INDEX TO THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

January-June, 1910

If it is desired to remove the index for the purpose of binding with The Journal for January to June, raise the staples upright, when the section will slip off easily. Then flatten the staples again.

INDEX TO JOURNAL, JANUARY-JUNE, 1910

NOTE: Items appearing in The Journal as Society Affairs, have the month and page number given. Where the list of discussors of a paper is given, the list appears under the straight title of the paper. Papers published in The Journal for 1909, discussion of which was published in 1910 are indicated by the month followed by "1909." All papers, reports, etc., of the Gas Power Section appear under the heading Gas Power Section. All items concerning colleges and not referring to Student Branches are indexed under Colleges. Items regarding Student Branches are so indexed. Miscellaneous items are indexed under Miscellaneous.

INDEX TO THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

JULY-DECEMBER, 1910

If it is desired to remove the index for the purpose of binding with The Journal for July to December, raise the staples upright, when the section will slip off easily. Then flatten the staples again.

INDEX TO JOURNAL JULY-DECEMBER, 1910

Note: Items appearing in The Journal as Society Affairs, have the month and page number given. Where the list of discussors of a paper is given, the list appears under the straight title of the paper. Papers published in The Journal previous to July, discussion of which was published during July to December, are indicated by the month followed by "1910." All papers, reports, etc., of the Gas Power Section appear under the heading Gas Power Section. Items regarding Student Branches are so indexed. Miscellaneous items are indexed under Miscellaneous.

THE PROFESSION OF ENGINEERING

PRESIDENTIAL ADDRESS 1909

By President Jesse M. Smith, New York

Great engineering works existed in many parts of the world long before Columbus discovered America. We have but to consider the ruins left by the Incas in South America and the Aztecs in Mexico to realize the great work done on this continent in engineering. In Asia the great wall of China, the temples of Japan, China, Babylonia and Assyria bear record of the presence of the engineer.

2 In Africa, the vast pyramids of Egypt and the temples on the Nile are evidences that great engineers existed long before the Christian era. We marvel still when contemplating the pile of immense blocks of stone forming the pyramids and try to imagine what form of apparatus could have been used in placing those great stones one upon the other.

3 In Europe the Greeks and Romans did marvelous work in roads, bridges, aqueducts, and various mechanical structures which the modern engineer may well ponder upon and admire. While we read much in history of the emperors and kings who reigned when these great engineering works were produced, we learn little of the men who produced them, men whom we now call engineers.

4 While engineers have existed for thousands of years it is only within a comparatively recent time that they have begun to form themselves into societies for their mutual education and the advancement of the profession of engineering.

5 In England, as early as 1771, Smeaton and his contemporaries came together to form the Smeatonian Society of Engineers, which, therefore, according to the calculations of a noted English engineer, is five years older than the United States. The Institution of Civil Engineers of Great Britain came into existence in 1818, and was followed by its sister society, the Institution of Mechanical Engineers, in 1847. La Société des Ingénieurs Civils de France was founded in 1848. Die Verein Deutscher Ingenieure was organized in 1856.

Presented at the Annual Meeting of The American Society of Mechanical Engineers, December 1909.

6 In this country the Boston Society of Civil Engineers began its work in 1848. Our elder sister among national societies, the American Society of Civil Engineers, was organized in 1852. The next member of the family, the American Institute of Mining Engineers, was born in 1871. Our own Society came into existence in 1880, and our younger and very vigorous sister, the American Institute of Electrical Engineers, came along in 1884.

7 Each of these four national societies, the American Society of Civil Engineers, the American Institute of Mining Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers, has grown greatly since its organization, and each continues to thrive. During the process of upbuilding of these four great national societies, several other national societies of specialists in engineering and many local societies of engineers have been formed, and all of these also are active and thriving.

8 The four greater national societies have an aggregate membership at this time of over 19,000 members. Twelve national societies of engineering specialists contain more than 13,000 members. Twenty-three local engineering societies in different cities of the United States count over 8,600 in their membership.

9 What does this great army of over 40,000 engineers, organized into many different societies, all for purely professional purposes, mean? It means that the engineering profession is making itself felt in this country of ours,—that it proposes to take a prominent place in the great activities by which the country is being developed,—that it will take its place in public affairs,—that it is coming into its own.

10 The national societies are not antagonistic to each other; on the contrary, they support and give confidence to each other. The national societies of specialists are not at war with the other national societies; they supplement them.

11 The local societies are not in opposition to the national societies; they extend their influence; they are the outposts of the great army. The specialists do not interfere with each other. We are all specialists to a greater or less extent; but we are all *engineers*.

12 In the legal profession, some men practice in the criminal courts: others devote themselves to titles in real estate; others are in corporation law; others practice in patent causes; they all squabble with each other in their practice; but when they meet in their bar associations they are all lawyers; they stand by each other and their profession; they are a power in the world.

13 The medical profession is made up of surgeons, oculists, aurists, general practitioners, specialists of the skin, the heart, the lungs and every other part of the human anatomy; but when they come together in their general medical associations they are all doctors; they also stand by each other and their profession; they also are a power in the world.

14 In the engineering profession why may not the men who practice in steam engineering; in machine construction; in hydraulics; in railroad, bridge, mining, electrical and chemical engineering; in metallurgy, refrigeration, heating and every other specialty in engineering, come together, stand by each other and their profession, become known as ***engineers*** and be a power in the world?

15 When, in 1889, the Institution of Civil Engineers of Great Britain invited the four national American societies of civil, mining mechanical and electrical engineers to visit it in London, there was inaugurated a spirit of friendship and coöperation in the engineering profession which has grown stronger and stronger as the years have passed. Following the visit in London, La Société des Ingénieurs Civils de France, in the same year, invited the American societies to Paris.

16 Those who were fortunate enough to participate in those memorable demonstrations of hospitality cannot fail to realize how greatly the seed of coöperation sown in that year has fructified.

17 In 1900 this Society was again invited by the Institution of Civil Engineers and the Institution of Mechanical Engineers to visit them in England, and again invited by the French society to visit it in Paris. Thus the spirit of coöperation was still further advanced by these remarkable meetings. On both occasions the sister societies abroad were untiring in the entertainment of the American engineers.

18 The year 1904 was made memorable by the acceptance of an invitation extended by this Society to the Institution of Mechanical Engineers of Great Britain to hold a joint meeting in Chicago. Thus the spirit of coöperation and good friendship was again strengthened and extended.

19 Now the Institution of Mechanical Engineers of Great Britain has expressed the desire to still further promote this friendly spirit by inviting this Society to a joint meeting in July of 1910 in England. The Council of our Society has accepted this very cordial invitation of the Institution in the spirit of good will in which it was extended. It remains for the membership of The American Society of Mechani-

cal Engineers to respond to this spirit and to go to England next year with its best talent and its best men.

20 The helpful coöperation in professional work which has already been established with our sister societies over the seas is also becoming manifest in our own country. The four national societies of civil, mining, mechanical and electrical engineers on March 24, 1909, held in this auditorium a joint meeting on the "Conservation of the National Resources," which did much to bring engineers close together and into coöperative relation.

21 Our Society invited the Boston Society of Civil Engineers to join in the monthly meetings of the Society recently held in Boston. The Engineers' Club of St. Louis in like manner was asked to join with us in the Society's monthly meetings recently held in St. Louis. In both cases the invitations have been accepted in the best spirit of coöperation.

22 The engineering societies of the country may be likened to the members of a large and harmonious family, each member independent to do its own special work in its own way, each member ready to help each of the others, each residing in its own home, but all ever ready to stand by each other, to work for the common good, to advance and dignify the profession of engineering.

23 A striking example of the "getting together" of the engineering societies is found in this building which is the home of our Society. It is also the home of our sister societies, the American Institute of Mining Engineers and the American Institute of Electrical Engineers.

24 Under the same roof are grouped together fifteen other societies of engineering and allied arts. 25,000 engineers practicing in all the specialties of engineering may call this building their professional home. We are living together here in peace and harmony. We have brought our books together into a single library open to the profession and to the public, where every person is welcome.

25 Our meetings are held in the same auditorium and lecture halls; the doors stand open that all who wish may enter. Our professional brethren of every society of every country are welcome here. The large hall at the entrance to the building is a foyer where all engineers may come together on the same plane, where they may unite to strengthen each other, to sustain and advance the profession of which they form a part.

26 The spirit of coöperation which now exists must be fostered, strengthened, made enduring, to the end that as great solidarity will

exist in the engineering profession as exists in any of the other great learned professions.

27 Numbers in membership are, of course, important in the societies which represent the engineering profession, but a high standard of membership is of much greater importance.

28 With a considerable number of high-grade technical schools throughout the country all striving with each other to raise the standards of engineering education ever higher and higher; and with the graduates from these institutions taking, from year to year, a larger and more responsible part in the great activities of the country, there is no lack of high-grade material from which to form a membership in the engineering societies which will be worthy of the profession.

29 In the Institution of Civil Engineers, as well as in the Institution of Mechanical Engineers, of Great Britain, we are informed, no person is admitted into the lower grade of membership unless he can pass a satisfactory examination as to the fundamental principles of engineering, by an examining board of the Institution. The rules laid down by this examining board form the standard by which the applicants to membership are measured. If the technical schools in Great Britain maintain an equally high standard in granting their degrees in engineering, then the degree may be accepted in lieu of an examination.

30 In other words, the engineering institutions in Great Britain establish the standard for the degrees granted by the technical schools. A promotion from a lower to a higher grade of membership is only made upon a showing of sufficient experience in engineering to satisfy the rules laid down by the Institution.

31 In The American Society of Mechanical Engineers, a person may enter the Society as a Junior upon the presentation of a degree in engineering from a technical school. But this Society has not, up to the present, established a standard by which to measure that degree. I believe the standard for such a degree in engineering should be established by the Society, and that it should be as high as that of the best schools of engineering in this country. It will follow that the schools having a lower standard will soon be brought up to the higher standard.

32 Promotion to higher grades of membership in our Society is only made upon a showing of engineering experience satisfactory to our Membership Committee. This committee is maintaining a high standard of membership, and I believe that acting under the influence of the membership and the Council of the Society, it will not allow that standard to fall, but rather cause it to rise.

33 If we are to have a profession of engineering, as distinguished from the trade of engineer, we must have a broad education befitting men of a learned profession, as distinguished from a narrower education sufficient for men of a trade.

34 President Lowell of Harvard in his recent remarkable inaugural address, gave this as his conclusion: "The best type of liberal education in our complex modern world aims at producing men who know a little of everything and *something well.*" If that conclusion be true of a liberal education leading to the learned profession of the law or medicine or theology, why is it not also true of a scientific education leading to the learned profession of engineering?

35 If preponderance be given to one part of President Lowell's conclusion over the other part, certainly knowing "a little of everything" leads to superficiality; while just as surely knowing but one thing well leads to narrowness. There would seem to be a happy mean between these two extremes, in the education of the engineer.

36 The engineer capable of being at the head of the larger engineering works must know something of many things, several things well and one thing profoundly.

37 The engineer president of a great railway system, for example, must know *something* of the alignment and gradients of the permanent way, its construction and maintenance; *something* of the proper location of sidings and stations; *something* of the system of signals, of the various kinds of cars, of the quality of water for the locomotives, of the heating and lighting of cars, and many other things. He must know *well* that the bridges have been designed for safety and endurance and that they have been properly constructed. He must know *well* that the tunnels are safely protected against external pressure and falling rocks. He must know *well* that the locomotives for drawing the high-speed trains, as well as those for the heavy freight trains, are of the very best design and capable of performing their duty with efficiency, economy and endurance. He must know *well* how to manage the traffic and keep the accounts. He must know *profoundly* how to coördinate all the different parts of this complex organization so that each part will perform its proper and full function, to the end that passengers and freight will be carried safely, surely, quickly and cheaply, and also that dividends will be paid to the shareholders.

38 The engineer knowing something of many things, several things well and one thing profoundly, is still one-sided if all this knowledge is confined strictly to his profession. He will be a much

broader man and a better engineer, if in his leisure hours he can turn his thoughts entirely away from his professional work and toward those things in nature and art which give that rest and renewal of the professional mind necessary to continued work.

39 Engineers have known for many years that the profession of engineering is a learned profession; the rest of the world is rapidly arriving at the same conclusion.

40 When in April, 1907, this building was dedicated "To the advancement of Engineering Arts and Sciences," President Hadley of Yale, where the learned professions have been taught for nearly 200 years, said:

> The men who did more than anything else to make the nineteenth century different from the other centuries that went before it, were its engineers.
>
> Down to the close of the eighteenth century the thinking of the country was dominated by its theologians, its jurists, and its physicians.
>
> These were by tradition the learned professions, the callings in which profound thought was needed, the occupations where successful men were venerated for their brains.
>
> It was reserved for the nineteenth century to recognize the dominance of abstract thought in a new field—the field of constructive effort—and to revere the trained scientific expert for what he had done in these lines.
>
> Engineering, which a hundred years ago was but a subordinate branch of the military art, has become, in the years which have since elapsed, a dominant factor in the intelligent practice of every art where power is to be applied with economy and intelligence.

It is encouraging to engineers to have their profession recognized as a "learned profession" by so great an authority as the president of Yale University.

41 Enthusiasm and devotion to his profession is characteristic of the engineer, and from my observation these begin with the student in engineering and extend right through his life. President Wilson of Princeton, in an address at Harvard not long since, dwelt upon "the chasm that has opened between college studies and college life. The instructors believe that the object of the college is study, many students fancy that it is mainly enjoyment, and the confusion of aims breeds irretrievable waste of opportunity." These conditions, I believe, exist to a much smaller extent in the technical schools, where engineers are taught, than in the general colleges, where a liberal education is obtained.

42 Enthusiastic love of work, for his profession's sake, resides in the heart of the engineer who becomes great. The man who merely works for wages, and without enthusiasm, does not rise; he remains a paid servant, and poorly paid at that.

43 Where enthusiasm exists, love of work exists; success follows. Our individual enthusiasm is quickened by the study of the work of our brother engineers.

44 What engineer while being whisked through the tunnels which connect Manhattan Island with the lands surrounding it, can fail to rejoice in his profession as he contemplates the work of the civil engineers, the mining engineers, the mechanical engineers, the electrical engineers, which, joined together, supplemented each other to produce success in those marvelous undertakings? The highest knowledge and skill in each of the four branches of the engineering profession were called for, and were forthcoming, in the consummation of this great work. It is not a question of which engineers did the most toward the success of this problem in transportation; they all did their best; they all did well; each contributed a necessary part to the success; they were all engineers working for the advancement of the profession of engineering.

45 Will not every true engineer feel his enthusiasm in his profession quicken, as he watches the great vessels of trade and the great vessels of war sweep out to sea, and he stops to consider how much of brains, and long experience, and hard work of many men are concentrated in each one of them?

46 We marvel still, our enthusiasm is inspired, as we see ponderous steam locomotives and mysterious electric locomotives competing in the hauling of trains, ever heavier and heavier, ever faster and faster, and both succeeding.

47 The automobile in its present highly developed and thoroughly practical form is the result of enthusiastic work of many engineers principally within the last fifteen years.

48 The enthusiasm of the engineer is never satisfied. Having conquered the highway with the automobile driven by the internal combustion gas engine, he now proposes to conquer the air with the aëroplane driven by the same kind of an engine in improved form.

49 The American Society of Mechanical Engineers has before it a future of usefulness to its members and influence in the profession, which is unlimited. It only requires that we stand by our tradition of increasing the membership with men of high quality as engineers; that the members maintain enthusiastic devotion to good professional work; that they coöperate with each other in the broadest and most friendly spirit to produce that solidarity of membership, and devotion to high ideals, which will compel the world to class the profession of engineering with the other learned professions.

EXPERIMENTAL ANALYSIS OF A FRICTION CLUTCH-COUPLING

By Prof. Wm. T. Magruder, Columbus, O.
Member of the Society

The following series of experiments was recently made to determine the results from the application of a known force at the end of the shifter lever of a friction clutch-coupling. Several 24-in., four-jaw friction clutch-couplings were used. They were the stock couplings made by the Falls Rivet & Machine Company, of Cuyahoga Falls, O. They consisted of the usual shifter lever, fork, yoke and cone, sliding on the driving shaft. The clutch arm *G*, Fig. 1, was a heavy casting keyed to the shaft *D*. Guide surfaces *H* were machined in each arm of the casting *G*, in which slid the inner jaws *I* and the outer jaws *J*. Each of the four pairs of jaws *I* and *J* was connected by pins *K* to the wedge-block *L*, which was fulcrumed at its center *M* in the clutch-arm casting. The wedge-blocks *L* carried adjustable steel wedges *N*, whose inner ends *O* engaged the short and hardened ends *P* of the cone-levers *Q*, and whose longer ends *R* were operated through the double links *F* by the sliding cone *E*. The inner and outer jaws engaged the annular ring *S* which was keyed to the driven shaft. This ring was 24 in. external diameter and 23 in. internal diameter. The eight jaws were each lined with a maple block $2\frac{1}{8}$ in. by 9 in. in size.

2 The tests included five lines of investigation:

First: To determine the forces required to throw in the shifter lever at different speeds when the clutch was in motion and when the clutch was at rest, and before and after the load had caused the clutch to slip on the ring.

Second: With different adjustments of the wedges, to determine the relation of the forces applied at the end of the shifter lever at different points in its motion and the cor-

responding axial forces, to the forces caused thereby to be exerted by the clutch shoes upon the ring of the clutch pulley.

Third: To determine the frictional resistances between the clutch shoes and the ring of the clutch-coupling, in motion and at rest under different loads.

Fourth: To determine the power transmitted for different adjustments of the wedges corresponding to different forces required to throw in the shifter lever, including the

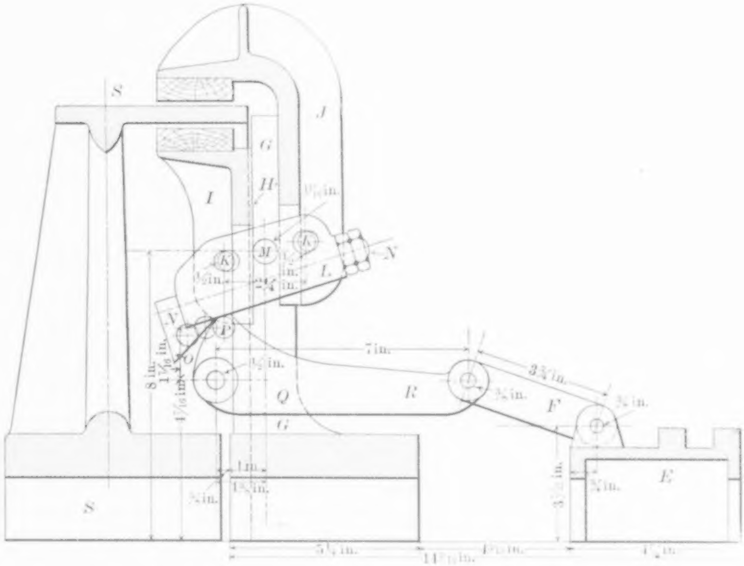

FIG. 1 HALF SECTION OF FRICTION CLUTCH-COUPLING.

maximum power which the clutch was capable of transmitting, and the maximum power which it was capable of picking up from rest.

Fifth: To determine the relation of the maximum forces applied at the end of the shifter lever, and the corresponding axial forces, to the maximum power transmitted by two-arm and four-arm clutches for the same adjustment of the wedges.

3 To make these tests, two machines were designed and constructed, as follows:

DYNAMIC CLUTCH-TESTING MACHINE

4 To determine the maximum power which a clutch was capable of transmitting when the load was either gradually applied or picked up from rest, the dynamic clutch-testing machine, Fig. 2, was used. It consisted of floor-stands *U*, two co-axial shafts *D* and *T*, $3\frac{7}{16}$ in. in diameter, and a large belt pulley *V* on the end of the driving shaft *D*, to which power was delivered. The clutch-coupling *G* was placed near the middle at the junction of the two shafts. The coupling was keyed to the driving shaft *D*, and the clutch-ring *S* was keyed to the driven shaft *T*. On the opposite end of the driven shaft the brake pulley *W* was keyed. The shifter-lever *A* was operated in a horizontal plane. The motions required to throw in the clutch-cone *E* were measured. The lever *A* was operated by hand power, or by screw power *B*, from behind a screen *Y* made of planks and used for the protection of the persons engaged in the test. There was a horizontal slit in it for the motion of the lever.

5 To measure the force exerted on the end of the shifter lever, a calibrated spring-balance *X* was used. It was of 300 lb. capacity, and was graduated by 5-lb. divisions.

6 The power was absorbed by a prony brake *Z* from the internally flanged, flat-faced pulley *W*, 48 in. in diameter, and 24 in. face. The length of the brake arm *Z* was $72\frac{5}{32}$ in. The brake constant was 0.001145 b.h.p. per lb. per revolution. The effort exerted by the brake beam was measured by a platform scale *C* of 2000 lb. capacity. The leverage of the shifter lever *A*, when normal to the shaft *D*, was 4.939 in the dynamic clutch-testing machine. It is to be regretted that the power available was not sufficient to keep the speed uniform at 100 r.p.m., and for this reason the machinery slowed down to 92 r.p.m. under the heaviest loads.

STATIC CLUTCH-TESTING APPARATUS

7 In order to determine the force with which the shoes pressed against the clutch ring when a given maximum force was required to throw the shifter lever into operation, a static clutch-testing apparatus, Fig. 3 and Fig. 4, was used. It consisted of a clutch arm *G* mounted on a vertical shaft *D* supported in a flange coupling fixed to a structural steel frame *a*. Only the two opposite arms of the clutch were used in this apparatus. The inner jaws were removed. The shoes of the two outer jaws *J* were caused to press upon a dummy

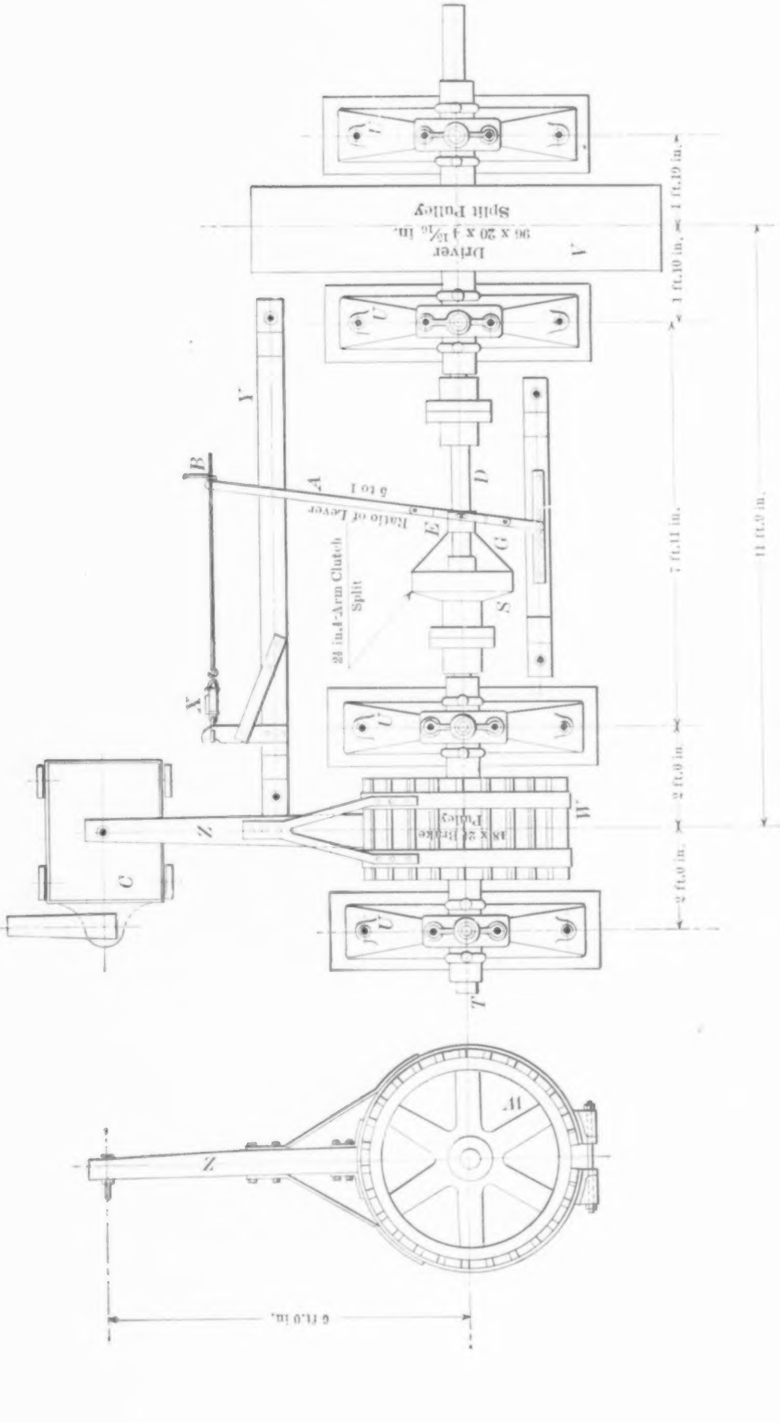

FIG. 2 DYNAMIC CLUTCH-TESTING MACHINE

ring made up of two separate cast-iron segments *b*. Each of these segments was connected by the links *c* to the yoke *d*, which in turn was connected through turnbuckle *e* to an eye carrying double knife edges *f*, which engaged the short and vertical end *g* of a bell-crank lever fulcrumed on a knife edge *h* in the frame *a* of the apparatus. To the longer and horizontal arm *i* of the bell-crank lever was knuckled a vertical prop *j*, the lower end of which was conical and which bore in a center-punch mark made in an iron bar resting upon a platform scale *k*, of 600 lb. capacity. The ratio of the arms was seven. Two platform scales were used, one for each dummy ring segment.

8 The parts of the mechanism were adjusted so that the knife edges were kept in position and bore fairly. The ring segments were so located that their external diameter was 24 in., or the same as the clutch ring. This was done by means of the turnbuckles. When the ring segments were in this position the wedges were adjusted to make the maple shoes bear evenly. The shifter lever was thrown in by screw power *B* and the force so required was measured frequently at definite intervals which were determined by measuring the distances which the cone *E* had been moved from its original position. The leverage of the shifter lever *A*, when normal to the shaft, was 4.863 to 1 in this apparatus.

9 In using the dynamic clutch-testing machine, the maple shoes were first adjusted by means of the wedge nuts so that they bore evenly. They were then burned in by driving the shaft *D* and the coupling *G* while the ring *S* was prevented from rotating. The wedge nuts were then adjusted again to make the shoes of both outer and inner jaws bear evenly on the ring when the shifter lever was thrown in.

10 This adjustment was tested by means of 16 copper strips, ½ in. wide, 0.002 in. in thickness, one used at each end of each shoe. If the shoes did not bear evenly, or at least as well as they are supposed usually to do in ordinary good millwright's practice, the wedge nuts were screwed up, the ring blocked from rotating, the lever thrown in, and the shoes again burned in. By this means fairly uniform results and even pressures were obtained between the eight shoes and the ring. With the shifter lever thrown in and the copper strips just capable of being pulled out by hand, the counting of the rotations of the wedge nuts was begun. Similar adjustments were made on the static clutch-testing apparatus, except that the shoes had been surfaced but not burned in.

11 In the tests, the wedge nuts were all screwed up, one turn or

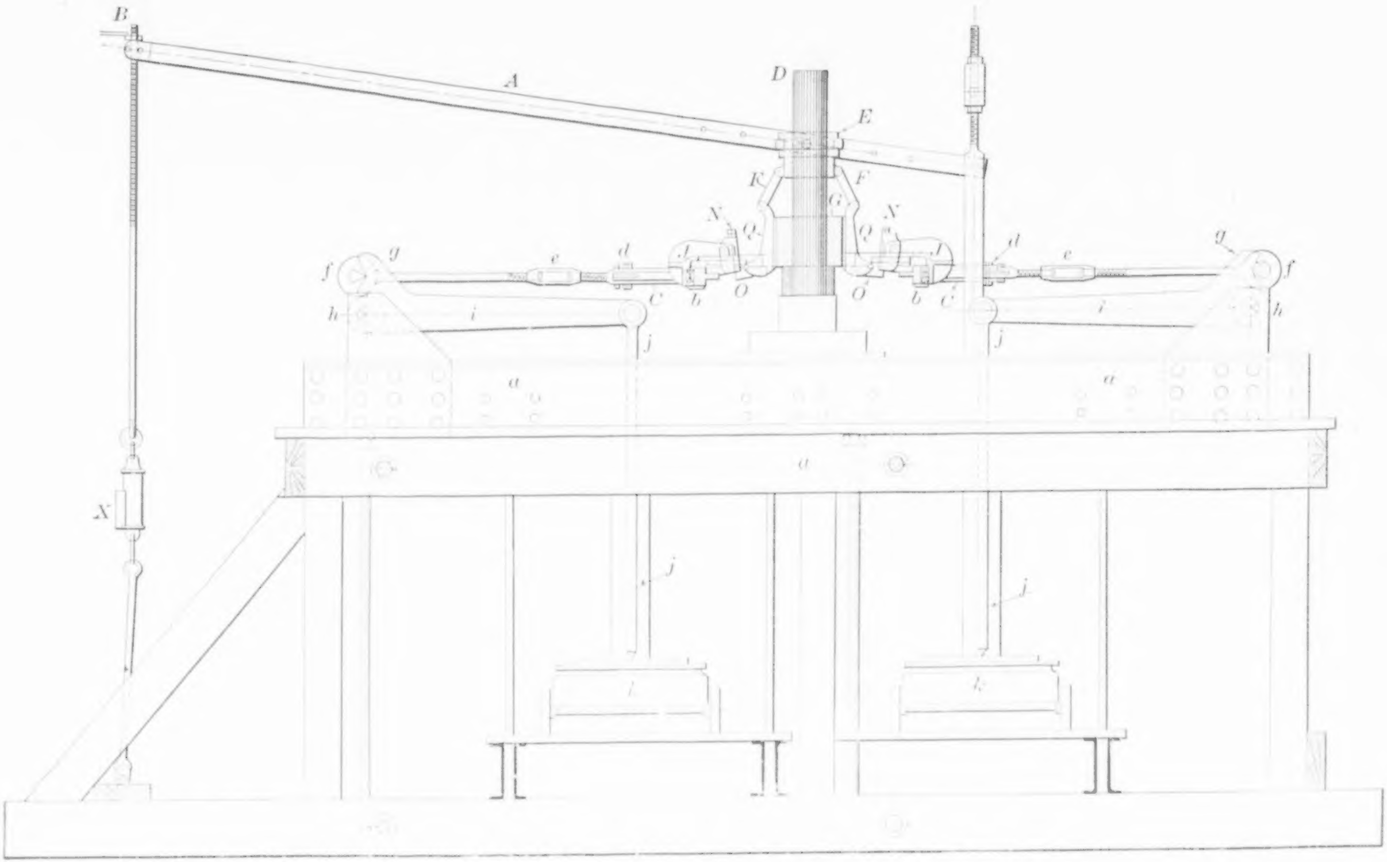

FIG. 3 STATIC CLUTCH-TESTING APPARATUS

less at a time, and the tests made, then another turn, and so on. When the shifter lever A was thrown in by hand power, a man applied his muscular effort to the spring balance X on the end of the lever: when it was thrown in by screw power, the tail-nut B was rotated. The spring balance had a maximum indicator besides the usual one. The motions of the cone E of the different couplings tested varied from 4 in. to $4\frac{1}{2}$ in. Readings of the spring balance were usually taken for each $\frac{1}{4}$-in. or $\frac{1}{2}$-in. motion of the cone.

FIRST SERIES OF TESTS

12 These were made to determine the forces required to throw in the shifter lever at different speeds, when the clutch was in motion and when the clutch was at rest, and before and after the load had caused the clutch to slip on the ring.

13 Tests G, H, I, and M were made on the dynamic clutch-testing machine. The forces required to throw in the shifter lever by screw power and by hand power when the shafts were at rest were first determined, the machine then started up, and the brake tightened until the clutch-coupling slipped on its ring. The brake was then loosened and another test made with the result that less power was transmitted. The wedge nuts were then tightened and the forces required to throw in the shifter lever were measured one or more times and the test continued, as given in Tables 1 and 1-A. In Test M, Table 1-A, readings of the forces required to throw in the shifter lever were taken both when the shafts were at rest and when they were in motion. The shifter lever was thrown in several times and the power determined for a fixed setting of the brake nuts. These were then tightened, and another set of four or more readings taken of the force required to throw in the shifter lever by hand power when the shaft was in motion.

14 With the wedge nuts screwed up two and one-half turns it required a maximum of 70 lb. to throw in the shifter lever by screw power. Immediately thereafter it required maxima of 55 lb. on the first trial, 45 lb. on the second trial, and 43 lb. on the third trial, to throw in the shifter lever by a steady pull by hand power. This shows that the force required to throw in the shifter lever by hand power was much less than by screw power. While this was partly due to the friction of rest being greater than the friction of motion, it was also partly due to the various parts of the clutch adjusting themselves to the conditions after one or two engagements of the

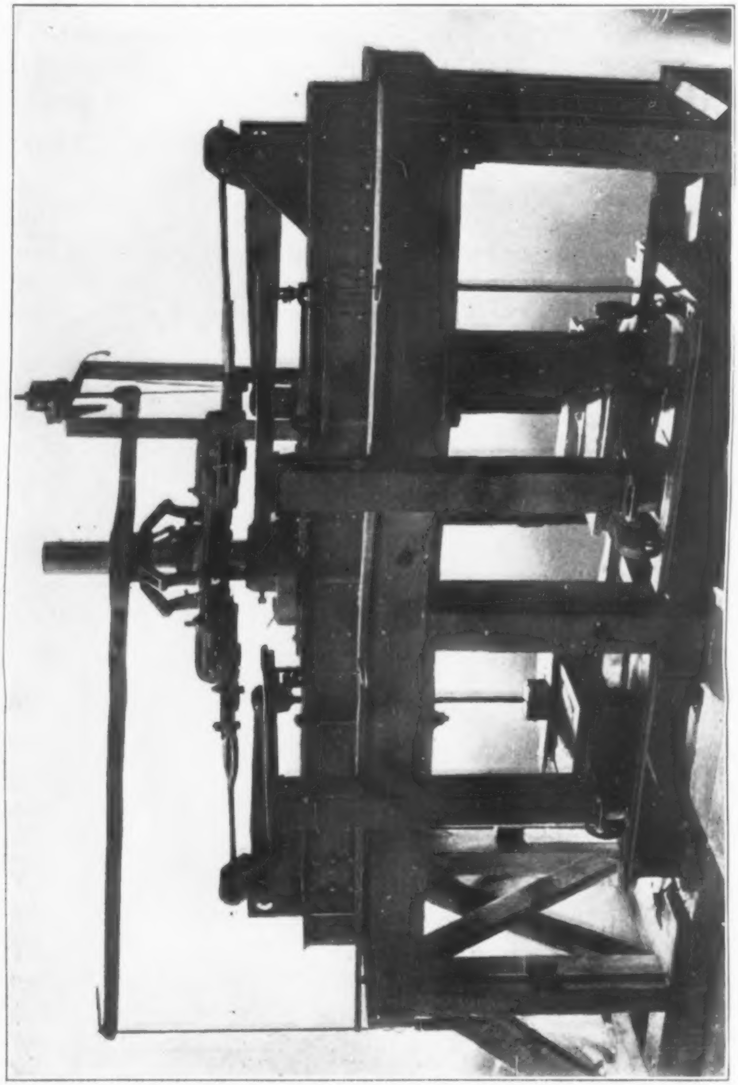

FIG. 4. GENERAL VIEW OF THE STATIC CLUTCH-TESTING APPARATUS

shoes with the ring. This has been frequently noted in practice in the shop.

15 With the same adjustment of the wedges, the clutch slipped when transmitting 84.6, 71.1, and 65.0 h.p., on the first, second, and third sets of trials. This reduction in the brake load shows the effect of wear of the clutch shoes due to the slipping on the ring. This was also indicated by the fact that it required a maximum of only 31 lb. to throw in the shifter lever by hand power after the test.

TABLE 1 FORCES REQUIRED TO THROW IN SHIFTER-LEVER AND HORSE-POWER TRANSMITTED

DYNAMIC CLUTCH-TESTING MACHINE

Wedges Set Up Turns	Distance From Start	Max. Force Required to Throw in Lever with Shaft at Rest. By			Corresponding Axial Pressure. Shaft at Rest. By		Gradually Applied Loads		
		Screw Power	Hand Power	Ratio	Screw Power	Hand Power	Net Brake Load	Rev. per Min.	Brake Horse-Power
Tests G. 24-in., Four-Arm, Solid Clutch-Coupling.									
1.5	2.75	53			277		581	96	63.9
							497	96	54.6
							471	96	51.8
2.5			119			588			
			94			464			
			75			371			
3.0			92			454			
			75			371			
3.5			114			563			
			92			454			
			92			454			
3.5	2.5	103	91	0.883	509	450	1185	92	124.8
		87[1]			430[1]				
Tests H. 24-in., Two-Arm, Solid Clutch-Coupling.									
3.5	2.5	45			222		471	96	51.8
							491	96	54.0
							486	95	52.9
4.0	1.875	114			563				
	2.25	111			548		735	95	79.9
		80[1]			395[1]				

[1] After test and after slipping.

TABLE 1—Continued

Wedges Set up Turns	Distance From Start	Max. Force Required to Throw in Lever with Shaft at Rest. By			Corresponding Axial Pressure, Shaft at Rest. By		Gradually Applied Loads		
		Screw Power	Hand Power	Ratio	Screw Power	Hand Power	Net Brake Load	Rev. per Min.	Brake Horse Power
Tests I. 24-in., Four-Arm, Split Clutch-Coupling.									
2.5	2.5	70	55	0.79	346	272	......	......	......
......	......	......	45	0.64	......	222	......	......	......
......	......	......	43	0.61	......	212	739	100	84.6
......	......	......	......	......	......	......	621	100	71.1
......	......	......	......	......	......	......	568	100	65.0
......	......	......	31[2]	0.44[2]	......	153[2]	......	......	......
3.5	......	85	65	0.76	420	321	......	......	......
......	......	......	67	0.788	......	331	915	96	100.6
......	......	......	55	0.646	......	272	......	......	......
......	......	......	53	0.623	......	362	......	......	......
4.5	2.25	133	99	0.74	657	489	......	......	......
......	......	......	100	0.75	......	494	1216	94	130.9
4.5	2.00	179	139	0.78	884	689	......	......	......
......	......	......	119	0.67	......	588	......	......	......
......	......	......	119	0.67	......	588	......	......	......
......	......	......	117	0.65	......	578	1371	93	146.0

[2] After test and after slipping. Reduction in b.h.p. shows effect of wear of shoes.

16 After two more sets of trials with tighter adjustments of the wedges, 130.9 h.p. was transmitted at 94 r.p.m.

17 With the wedge nuts screwed up four and one-half turns, it required a maximum of 179 lb. to throw in the shifter lever by screw power, and of 119 lb. to throw it in by a steady pull by hand, corresponding to 884 lb. and 588 lb. respectively, of axial thrust. Under these conditions, when transmitting 146 h.p. at 93 r.p.m., the split clutch broke. This is 77.7 per cent of the breaking load carried by the four-arm solid clutch.

18 From Tests G and I, Table 1, it will be seen that the force required to throw the shifter lever in by a steady pull by hand power, the first time, varied from a minimum of 66.5 per cent to a maximum of 88.3 per cent, averaging about 76.8 per cent of the force required to throw in the shifter lever by screw power; and that the force required to throw in the shifter lever by hand power, after the test,

TABLE 1-A FORCES REQUIRED TO THROW IN SHIFTER-LEVER AND PICKUP LOAD

Wedges Set Up Turns	Max. Force Required to Throw in Shifter-Lever. Shaft at Rest: Screw Power	Max. Force, at Rest: Hand Power	Max. Force, in Motion: Hand Power	Max. Force, in Motion: Ratio	Number of Trials Averaged.	Corresponding Axial Pressure. Shaft at Rest: Screw Power	Axial Pressure, at Rest: Hand Power	Axial Pressure, in Motion: Hand Power	Pick-up Loads: Actual Net Brake Load	Pick-up Loads: Estimated rev. per Min.	Pick-up Loads: Equivalent Brake Horse-Power
Tests M., 24-in. Four-Arm, Solid Clutch-Coupling.											
2.0	67				1	331					
		61		0.91	3		301				
			58	0.87	5			258	94	102	11.0
			44	0.67	4			217	206	100	23.6
3.0		124			4		612				
			93		5			459			
			86		4			425			
			69		4			341	543	96	59.7
4.0		140			1		692				
		125			6		617				
			115		4			568			
			105		5			519	501	96	55.1

varied from 44.3 per cent to 64.6 per cent, averaging 54.5 per cent of the force required to throw in the shifter lever by screw power before the test. From Tests I, the ratio of the forces required to throw in the shifter lever by hand power, before and after the tests, varied from 31/45 = 68.8 per cent to 54/66 = 81.8 per cent. It is to be noted that when the four-arm solid clutch broke, when transmitting 187.8 h.p., its wedges had been adjusted so that it required a maximum of 114 lb. to throw in the shifter lever by screw power, corresponding to a maximum of 563 lb. axial thrust. With the same axial thrust applied, the 24-in. two-arm clutch slipped when transmitting 79.9 h.p., or only 42.5 per cent thereof.

19 Tests L, Table 2, were made on the static clutch-testing apparatus. They give the forces required to throw in the shifter lever by screw power and by hand power. The ratios are higher than those given in Table 1 because there was no intermediate starting up, slipping and wearing of the clutch shoes. The last two tests were made with only one jaw in service, the other being disconnected.

20 From these tests it will be seen that the force required to throw in the shifter lever slowly and steadily by hand power averages on the static apparatus 88 per cent and on the dynamic machine about 79 per cent of that required to throw it in by screw power;

TABLE 2 TESTS L: FORCES REQUIRED TO THROW IN SHIFTER-LEVER, AND PRESSURES EXERTED BY CLUTCH-SHOES ON CLUTCH-RING

Tests on Static Clutch-Testing Apparatus. 24-in., Four-Arm, Solid Clutch-Coupling, Using Only Two Outer Jaws

Wedges Set Up, Turns	Distance from Start	Max. Force Required to Throw in Shifter-Lever Shaft at Rest by			Corresponding Axial Pressure Shaft at Rest by		Net Platform Scale Readings Corresponding to				Actual Shoe Pressures Corresponding to Maximum Force. Lever Ratio = 7					Ratio Column 16 to Column 3
							Column 3		Max. Net		To Throw in Lever		On Shoes		Total on Shoes	
		Screw Power	Hand Power	Ratio	Screw Power	Hand Power	W	E	W	E	W	E	W	E		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
3	1 5/16	44	....	.....	214	....	150	160	263	271	1050	1120	1841	1897	3738	85
3	1 9/16	44	....	.....	214	....	173	182	....	....	1211	1274	....	....	....	....
4	1 1/16	59	51	0.86	287	246	179	192	330	339	1253	1344	2310	2373	4683	79
5	13/16	77	68	0.86	374	331	207	225	400	409	1449	1575	2800	2863	5663	74
6	13/16	85	77	0.91	413	374	226	234	417	419	1582	1638	2919	2933	5852	69
6.5	9/16	97	90	0.92	472	435	203	216	453	460	1421	1512	3171	3220	6391	66
7	5/16	134	109	0.81	652	530	227	252	535	544	1589	1764	3745	3808	7553	56
7	9/16	110	100	0.91	535	486	249	261	500	504	1743	1827	3500	3528	7028	64
8	5/16	157	134	0.86	763	652	289	310	594	600	2023	2170	4158	4200	8358	53
Average				0.88	....	....	....	....	....	....	....	....	....	....	....	68
4	13/16	33	29	0.88	160	141	125	out of	277	....	875	....	1939	....	....	....
6.5	9/16	52	48	0.92	253	233	180	service	394	....	1260	....	2758	....	....	....

Maximum force required to throw in shifter-lever acting on outer jaw of only one arm:

By screw-power.. 33 lb.
By hand-power, steady pull.................................... 29 lb.
By hand-power, rapidly.. 31 lb.
By hand-power, more rapidly.................................. 37 lb.
By hand-power, suddenly, or by jerk........................ 55 lb.

that this ratio is reduced to about 0.68 by repeated trials of the mechanism when at rest; that the ratio of the forces required to throw in the shifter lever when the shafts are in motion and are at rest varies from 0.91 to 0.87 according to the number of slippings of the clutch on its ring, and may be reduced even to 0.67 after several slippings.

SECOND SERIES OF TESTS

21 The series was made to determine with different adjustments of the wedges the relation of the forces applied at the end of the shifter lever at different points in its motion and the corresponding axial forces, to the forces caused thereby to be exerted by the clutch shoes upon the ring of the clutch-pulley.

TABLE 3 TESTS L: FORCES REQUIRED TO THROW IN SHIFTER-LEVER AND CORRESPONDING PRESSURES EXERTED ON PLATFORM SCALES

TESTS ON STATIC CLUTCH-TESTING APPARATUS. 24-IN., FOUR-ARM, SOLID CLUTCH-COUPLING USING ONLY TWO OUTER JAWS

Distance Cone is Moved	Corrected Spring-Balance Readings of Forces Exerted at End of Shifter-Lever	Corresponding Net Platform Scale Readings	
Inches		West	East
$\frac{1}{16}$	18	8	12
$\frac{5}{16}$	43	55	65
$\frac{9}{16}$	53	102	116
$\frac{13}{16}$	57	144	159
$1\frac{1}{16}$	59	179	192*
$1\frac{5}{16}$	58	209	222
$1\frac{9}{16}$	53	235	248
$1\frac{13}{16}$	51	256	269
$2\frac{1}{16}$	48	271	287
$2\frac{5}{16}$	43	290	304
$2\frac{9}{16}$	38	303	314
$2\frac{13}{16}$	33	312	323
$3\frac{1}{16}$	32	318	330
$3\frac{5}{16}$	26	321	335
$3\frac{9}{16}$	23	326	337
$3\frac{13}{16}$	16	328	339
$4\frac{1}{16}$	8	330	339
$4\frac{5}{16}$	0	329	339†

* Maximum Force required to throw in shifter-lever.
† Maximum pressure on shoes.

22 Table 2 gives the results of the tests with the static apparatus. The maximum forces required to throw in the shifter lever by screw power and by hand power, and their ratio, the corresponding axial pressures, the corresponding net platform-scale readings, and the actual shoe-pressure readings for these two maxima, are given. "W" and "E" mean "west" and "east" and refer to the relative positions of the two scales on the left and right-hand sides respectively, as in Fig. 4.

23 Comparing the figures in the last column, which give the ratio of the sum of the maximum actual shoe pressures to the maximum force required to throw in the shifter lever, it is seen that the force ratio varies from 85 for three turns of the wedge nuts to 53 for eight turns of these nuts, with an average of 68. This shows that the efficiency is much greater under the lesser pressures.

24 The two tests at seven turns show the effect of compression in the form of set, not only on the shoes but on the various parts and joints of the clutch.

TABLE 4 TESTS F: FORCES REQUIRED TO THROW IN SHIFTER-LEVER, AND HORSEPOWER TRANSMITTED

TESTS ON DYNAMIC CLUTCH-TESTING MACHINE. 24-IN., FOUR-ARM, SOLID CLUTCH-COUPLING

Wedges Set Up, Turns	Distance From Start	Max. Force Required to Throw in Shifter-Lever. Shaft at Rest. By Screw-Power.	Corresponding Axial Pressure. Shaft at Rest. By Screw-Power.	Gradually Applied Loads.		
				Net Brake Load	Rev. per Min.	Brake Horse-Power
	$2\frac{7}{8}''$	51	252	556	90	57.3
	......	....	....	666	94	71.7
	......	....	....	606	97	67.3
One more turn..........	$2\frac{5}{8}''$	97	479	1112	92	117.1
One more turn..........	$2\frac{5}{8}''$	114	563	1665	94	179.2
				1745	94	187.8
Equivalent horsepower at 100 r.p.m.					100	199.8

25 The following statements are deduced from the results of this series of tests:

a The average ratio of the maximum forces required to throw in the shifter lever with one and two jaws was 0.55.

b The average ratio of the corresponding forces exerted on the ring with one and two outer jaws, counting the forces exerted by only one jaw in each case, was 0.79.

c The average ratio of the corresponding forces exerted on the ring with one and two outer jaws, counting the forces exerted by both the jaws, was 0.38.

d The average ratio of the maximum forces exerted on the ring with one and two outer jaws, counting the forces exerted by only one jaw in each case, was 0.85.

e The average ratio of the maximum forces exerted on the ring with one and two outer jaws, counting the forces exerted by both the jaws, was 0.42.

f In other words, 55 per cent of the force applied at the shifter lever produced only 38 per cent as much corresponding force exerted on the ring, and only 42 per cent as much of the maximum force exerted on the ring, for one jaw rather than two jaws. This was doubtless due to the inequality of the pressures exerted when only one arm was in use, and shows the desirability of so adjusting the wedges of the opposite arms that the shoes bear equally.

26 Table 3 shows the relation of the motion of the cone to the maximum force required to be applied at the end of the shifter lever and to the forces exerted by the clutch shoes upon the dummy ring-segments in Tests L, and is a fair sample showing that the maximum force exerted on the shifter lever does not produce the maximum force exerted on the clutch shoes.

TABLE 5 TESTS N: FORCES REQUIRED TO THROW IN SHIFTER-LEVER, AND HORSEPOWER TRANSMITTED WITH GRADUALLY APPLIED AND PICKED-UP LOADS

TESTS ON DYNAMIC CLUTCH-TESTING MACHINE. 24-IN., FOUR-ARM, SOLID CLUTCH-COUPLING.

Wedges Set Up, Turns	Distance From Start	Maximum Force Required to Throw in Lever. Shaft at Rest. By Screw-Power.	Corresponding Axial Pressure Shaft at Rest. By Screw-Power	Gradually Applied			Suddenly Applied Loads		
				Net Brake Load	Rev. per Min.	Brake Horse-Power	Net Brake Load	Rev. per Min.	Brake Horse Power-
3	2.5	53	263	711	96	78.2	471	96	51.8
3	2.75	43	212[1]						
4	2.25	90	445	1035	92	109.0	471	98	52.9
4	2.5	58	286[1]						
5	2.25	125	617	606	96	66.6	491	98	55.1
				606	96	66.6	561	96	61.7
				746	94	80.5	628	95	68.3
				621	93	66.1	981	91	102.2
							986	91	102.7
		Equivalent horsepower at 100 r.p.m.						100	112.8

[1] After slipping three times.

THIRD SERIES OF TESTS

27 The third series of tests was made to determine the frictional resistance between the clutch shoes and the ring of the clutch-coupling in motion and at rest.

28 For these tests, a cast-iron plate, $1\frac{15}{16}$ in. thick, 12 in. wide, and 36 in. long, and maple blocks $\frac{27}{32}$ in. thick, 3 in. wide, and 9 in. long were used. The angles of inclination of the plate at which a block would begin to slide from rest, and at which it would continue to slide after being started into motion, were taken as the angles of friction respectively for the two cases. The horizontal forces required to be exerted in order to start the block from rest, and to continue it in motion when placed on the carefully leveled plate, were taken to be the natural tangents of the angles of friction respectively for the weights carried by the block.

29 The smoothness of finish of the block, the uniformity and trueness of the bearing surface, the deflection of the plate, the cushion of air between the block and the plate, each has its effect on the angle of friction.

30 The number of tests made with flat maple blocks does not warrant the drawing of very positive conclusions, but it would seem that the average frictional resistance under load was greater from rest than the resistance under load in motion, in the proportion of the tangent of 18.5 deg. to the tangent of 13.3 deg., or in the proportion of 0.33 to 0.24.

FOURTH SERIES OF TESTS

31 The next series of tests was to determine the power transmitted for different adjustments of the wedges corresponding to different forces required to throw in the shifter lever, including the maximum power which the clutch-coupling was capable of transmitting, and the maximum power which it was capable of picking up from rest.

32 For these tests, the dynamic clutch-testing machine was used. The wedges were adjusted so that the shoes bore fairly equally. To determine the maximum power which the clutch-coupling was capable of transmitting, the wedge nuts were gradually tightened, and the brake screwed up either until the coupling slipped, in which case the wedge nuts were tightened up further, or else the clutch broke. Table 4 gives the results of this set of tests, from which it will be seen that with a maximum of 114 lb. applied by screw power at the end of the shifter lever, corresponding to an axial thrust of 563 lb., when revolving at 94 r.p.m. under a net brake load of 1745 lb. the clutch transmitted 187.8 h.p., under which condition the clutch slipped, the speed varying from 94 to 98 r.p.m., and both clutch and ring broke. This corresponds to 199.8 b.h.p., or practically to a maximum of 200 b.h.p., for a speed of 100 r.p.m.

33 Table 5 gives the results of the tests with the dynamic clutch-testing machine, of the forces required to throw in the shifter lever, and the horsepowers transmitted with gradually applied and suddenly applied loads. The latter are what are sometimes called pick-up loads. From this table it will be seen that with a net brake load of 986 lb., when running at 91 r.p.m., the clutch picked up 102.7 h.p. and had it started when the clutch broke. It had just previously picked up 102.2 h.p. This corresponds to 112.8 maximum b.h.p. of pick-up load for a speed of 100 r.p.m.

FIFTH SERIES OF TESTS

34 The last series was to determine the relation of the maximum forces applied at the end of the shifter lever and the corresponding axial forces, to the maximum power transmitted by two-arm and four-arm clutches for the same adjustment of the wedges.

35 To perform this test on the clutch which had been tested in the dynamic clutch-testing machine (See Tests H of Table 1), the two opposite pairs of jaws were disengaged by unscrewing their wedge nuts, and retaining the same adjustment on the two other pairs of shoes. It was found that it then required a maximum of 45 lb. to throw the shifter lever in by screw power, and that when revolving at 95 to 96 r.p.m. the clutch slipped at 51.8, 54.0, and 52.9 b.h.p. respectively. When the wedges were tightened up one half turn further, it required a maximum of 114 lb. to throw the shifter lever in by screw power. When running at 95 r.p.m. the clutch slipped when transmitting 79.9 h.p. After the test, it required a maximum of only 80 lb. to throw the shifter lever in by screw power.

36 Comparing the tests of these clutches, with four arms and two arms, the wedge nuts being turned up three and one-half turns in both cases, the horsepowers required to slip the clutch were found to be 124.8 and 52.9 (average of 51.8, 54.0, 52.9). This would seem to show that the two-arm clutch transmitted only 44 per cent as much power as would the same clutch with four arms for the same adjustment of the wedges. As the axial thrusts, however, were in the same proportion, 103 to 45, it would seem as though the horsepowers transmitted were directly proportional to the number of arms, whether two or four, and to the forces required to throw the shifter lever in by screw power, and therefore to the axial thrusts. No tests were made with six-arm clutches.

CONCLUSIONS

37 Applying the deductions of Tests L, Table 2, to Tests F, Table 4, we may say

A That at 100 r.p.m., with the shoes properly burned in and the wedges adjusted so as to give equal pressures between each of the eight shoes and the ring, and with no excessive lost motion between the jaws and their guides in the clutch-arm casting, a 24-in. four-arm solid clutch and ring will probably break:

a When transmitting 200 h.p., if gradually applied.

b When attempting to pick up a load exceeding 110 h.p.

B That to do so will require:

a A maximum force of between 100 lb. and 115 lb., applied at the shifter lever for a leverage of five.

b A maximum axial force or thrust on the collar of between 500 lb. and 600 lb.

c A combined maximum pressure of the eight shoes on the clutch ring of between 7500 lb. and 8000 lb.

d An intensity of pressure of about 50 lb. per sq. in. for each of the twenty square inches of each of the eight shoes of the four-arm clutch.

C That any inequality or lack of evenness and uniformity of the pressures with which opposite shoes bear on the ring, or any lost motion between the various parts, will decrease the breaking strength of the clutch.

D That a 24-in. four-arm split clutch will probably break when transmitting between 140 and 150 b.h.p. at 100 r.p.m., if the force is gradually applied and under proper conditions.

E That the factor of safety of 10, as used by the clutch manufacturer in this case, is quite ample.

AN ELECTRIC GAS METER

By Prof. C. C. Thomas, Published in The Journal for December

The following addition to his paper was given orally by Professor Thomas in presenting it before the Society at the meeting of December and should therefore be considered a part of the paper.—Editor.

THEORY OF THE METER AND METHOD OF OBTAINING STANDARD RESULTS

32 The figures given in paragraphs 14, 15 and 19 can be reduced to standard conditions of temperature and pressure, and the meter readings can be autographically recorded directly in "standard cubic feet" of gas or air. Let

G = cubic feet of gas per hour
E = energy in kilowatts

Then B.t.u. per hr. = 3412 E

T = temperature difference, deg. fahr.
S = specific heat per cu. ft.

Then $G\ S\ T$ = heat energy equivalent to E, or $GST = 3412\ E$. $\dfrac{GT}{E} = \dfrac{3412}{S}$ = a constant K which depends upon the specific heat of the gas.

33 Since the temperature difference T is kept constant, it follows that $\dfrac{K}{T}$ is constant. Let $\dfrac{K}{T} = C$. Then $G = \dfrac{KE}{T} = CE$.

34 It is now proposed to show by reference to the gas and the air curves in Fig. 10, that if the specific heat of gas made under given conditions be calculated from the customary chemical analysis and the specific heat of the constituents, then this specific heat may be used for determining the constant C. From the gas curve (Fig. 10), which was made with illuminating gas at an average temperature of

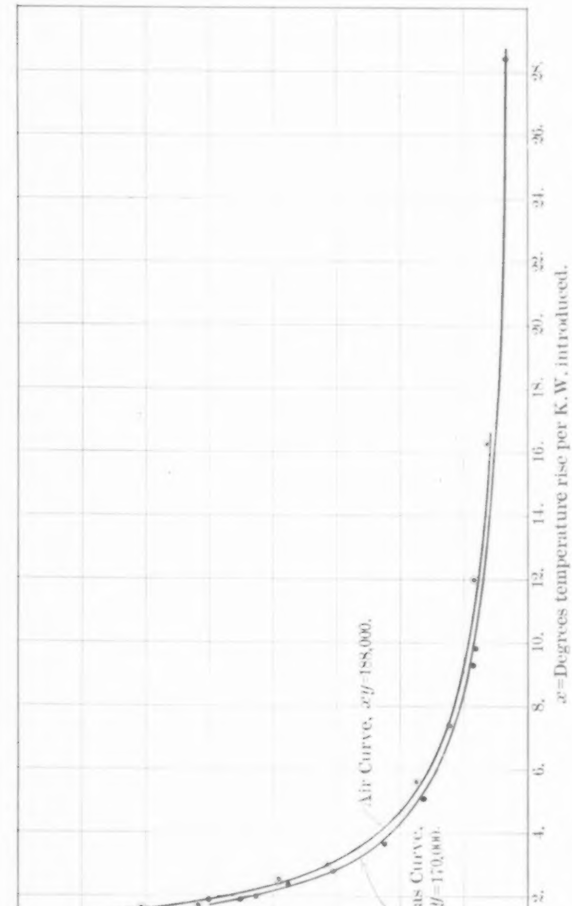

FIG. 10 SHOWING DEGREES TEMPERATURE RISE PER KW. FOR DIFFERENT RATES OF FLOW OF GAS AND AIR

59 deg. fahr., and under an average absolute pressure of 6 in. water and 29.8 in. mercury,

$$K = 170{,}000 = \frac{3412}{S}$$

35 Therefore for the condition of the gas when the tests were made the specific heat per cubic foot $= S\ \frac{3412}{170{,}000} = 0.0201$. If this be reduced to standard conditions of 32 deg. fahr. and 29.9 in. mercury, then $S = 0.021$, which is to be compared with the calculated specific heat (Par. 14), giving $S = 0.0211$. If the standard conditions are taken as 62 deg. fahr. and 29.9 in. mercury, the specific heat becomes 0.0198, and the constant becomes

$$K = \frac{3412}{0.0198} = 172{,}500, \text{ nearly}$$

If the temperature difference is kept constant at 5 deg. fahr., then $\frac{K}{T} = \frac{172{,}500}{5} = 3450 = C$, or $G = 3450\ E$.

36 The cross-section paper on the recording wattmeter is ruled so that 3450 E is read directly, instead of the watts E. The record is thus read directly in cubic feet of gas. The regular records of chemical analysis of the gas should be referred to from time to time in order to ascertain what percentage variation takes place in specific heat. It appears, as stated previously, that the elements which vary during the operation of a gas plant are not those whose variation would produce serious variation in specific heat. The variation that does take place is apparently well within the limits of accuracy practicable, or generally considered necessary in the operation of gas plants. By taking frequent chemical analyses the error can be reduced so as to be quite negligible.

37 The conditions during the air tests were as follows: barometer, 29.75; pressure, 6.5 in. water; average temperature of air as measured in the wet meter, 60 deg. fahr. From the air curve obtained under these conditions (Fig. 10)

$$K = 188{,}000, \text{ and } S = \frac{3412}{188{,}000} = 0.0181$$

38 Reducing this to standard conditions of 32 deg. and 29.9 in. mercury, $S = 0.0191$. This is to be compared with the accepted specific heat of air under these conditions, or 0.0192 B.t.u. per cu. ft.

This provides perhaps the best evidence that could be obtained, as to the accuracy of these tests, since the specific heat of air is well known at the conditions under which the tests were made. A more commonly familiar figure for specific heat of air is obtained by multiplying 0.0192 by the number of cubic feet of air per pound under the above conditions, or 12.38. The result is 0.2377 B.t.u. per lb. per deg. and this is to be compared with 0.0191×12.38 as given by the meter, or 0.2365.

39 The constant K for air at 32 deg. and 29.9 in. is therefore

$$\frac{3412}{0.0191} = 178{,}630$$

and reducing this to 62 deg. instead of 32 deg.

$$K = \left(1 \times \frac{30}{493}\right) \times 178{,}630 = 189{,}500 \text{ nearly}$$

If $T = 5$ deg., $\dfrac{K}{T} = 3790$.

40 The error involved in calling this constant 3800 is less than ½ of 1 per cent and well within the limits of accuracy possible under the circumstances. The standard cubic feet of air passing the meter are therefore $G = 3800\ E$, and the autographic records are arranged to read accordingly, in standard cubic feet of air per hour.

41 The development of a new device requires consideration of a large number of questions arising out of the conditions of service proposed. The question of specific heat has been considered in the preceding paragraphs. The degree of success which has been attained with this meter in accurately measuring specific heat is due principally to an extensive experience in this particular class of work, which has served to point out the way to make an electrical heater in which heat losses are negligibly small. The arrangement of the meter is such that the heat given off can go into the gas only, and it necessarily all goes into the gas, with the exception of a negligibly small loss which it is not worth while to minimize further. That the gas receives all the heat, excepting this negligibly small loss, is true whether or not the heating material has collected deposit of some kind. So long as the gas can get through the heater, its temperature is raised proportionately to the heat supplied.

42 The question of the presence of a small amount of water vapor, as part of the gas, has so far not introduced any complications. It

is conceivable that if the gas carried a large percentage of water the operation of the meter would be interfered with,—but so would the operation of a gas engine or a burner. The meter can apparently measure accurately any gas that can be used by a gas engine. The absence of moving parts in the meter gives it an advantage over the engine, and dust can be to a considerable extent deposited before entrance of the gas to the meter. The heating element and thermometers can be cleaned by dipping in gasolene, without damaging them.

43 Meters at present under construction are being made with the axis of the cylinder vertical, with a view to greater convenience of access and in making connections.

44 The first large meter of this type to be installed was put in the works of the Milwaukee Gas Light Company, and the writer is indebted to the officials of that company for their coöperation in making extensive tests during the work of development.

45 Referring to Par. **16**, for gas or air under the conditions existing during the tests, of approximately 60 deg. fahr., 29.8 in. mercury and 6 in. water pressure, the correction for water vapor introduces a change in the results of less than one-half of one per cent, and was therefore omitted. At other pressures and temperatures the correction for water vapor can be easily made by reference to the charts commonly used in gas works. An interesting confirmation of the statement in Par. 16 appeared during the tests, in that the most minute addition of electrical energy caused an immediate rise of temperature of the gas or air. This was repeatedly tried with great care, and always with the same result.

THE TRAINING OF MEN—A NECESSARY PART OF A MODERN FACTORY SYSTEM

By Magnus W. Alexander, Lynn, Mass.
Member of the Society.

Emerging from the depression of the last two years, American industries are once more entering upon an era of prosperity, which in the natural course of events should surpass in magnitude and intensity anything yet seen in the industrial world. One obstruction alone lies in the path of this unrivaled future: lack of men to do the work is the fact that confronts keen observers of the situation. There is no lack of enterprise in the country; money for sound business undertakings is plentiful; and the consuming capacity at home and abroad is increasing from year to year. But are we in a position to utilize these factors to the fullest extent?

2 Only a few years ago the cry for efficient men in all branches of industrial activity was universal and insistent, and manufacturers everywhere complained of their inability to man their establishments properly. Skilled mechanics were at a premium; capable industrial foremen and superintendents were painfully scarce; while positions of leadership calling for men of education, experience, and breadth of view could be filled only with difficulty.

3 The industrial depression of 1907–1908 naturally relieved the embarrassment; but even then skilled mechanics and efficient foremen could not be secured in adequate numbers. The last few months have already clearly demonstrated that the acuteness of the situation has returned, and that this condition will be accentuated as time goes on. Should we, then, not profit by the lessons of the past and cast about for an adequate remedy? Now is the time to analyze the situation, and in the light of our experience, work out a comprehensive policy which will enable us to cope with the exigencies as they arise. This is a matter which concerns every manufacturer, large and small; it is as much a problem of business sagacity as of immediate necessity.

4 In December 1906, I had the privilege of presenting to The American Society of Mechanical Engineers my ideas concerning the train-

ing of young men for positions as skilled mechanics and foremen, and of showing how this scheme had been put into practical operation through the apprenticeship system of the General Electric Company at West Lynn, Mass. In the meantime this system has been materially extended so as to provide adequately for the boy with a grammar school, a high school, or an engineering college education. New lines of factory work have been included, and cognizance has been taken of the necessity for training machine specialists. The educational scheme of the Lynn Works, therefore, presents in its present scope a comprehensive policy.

5 The underlying thought of all this training is the belief that skill will demonstrate its full potential value only as it is supported by intelligence. Each course of training, except in the case of machine specialists, includes, therefore, distinctive educational work, and the scope of each course is based on the previous education of the individual. There are, of course, young men of pronounced native ability, who, no doubt, would prove to be efficient in training courses from which the above educational requirement excludes them, but to deal with these exceptions would complicate the process of selection and the system of training. In the training courses for trade apprentices alone, which are ordinarily open to grammar school graduates only, boys with an incomplete grammar school education, who can pass a satisfactory examination, may be admitted; in all other courses rigidity of requirements is necessarily maintained.

6 In the training leading to positions as machine specialists, such as shaper, lathe and boring mill hands, milling machine operatives, etc., no provision has yet been made for educational advancement as distinctive from training for skill. This can be effected at any time, however, without undue expenditure.

7 The company recognizes the existence of workingmen who are in the class of unskilled labor from lack of opportunity or of foresight or due to other circumstances not under their control and for the same general reasons remain in such service. Many, of course, by disposition and general makeup, are bound to find their livelihood in such unskilled labor, while on the other hand, many can be trained in a comparatively short time to semi-skilled and skilled special work. Such training will increase their economic value and their contentment and add materially to the productive efficiency of the factory.

8 In pursuance of this policy a systematic effort is made to select from among the unskilled workers men of from 20 to 35 years of age, who give fair promise of success as machine specialists. Some of

these men are now receiving instruction in lathe work, others in shaper or boring mill, or planer or milling machine work. This training lasts from three to four months, depending on individual capacity, and the men receive during that time an hourly rate which gives them a living wage. A capable instructor makes the selection, assigns the men to the various factory departments where machines and work are available, and supervises their training.

9 These men are, of course, under the foremen in whose department they are working for the time being, but the instructor, who is a very capable skilled mechanic, having had charge of men for many years, visits them almost daily and sees that they receive work of an instructive character and of advancing difficulty, as far as this can be done without undue interference with the productive requirements of the factory. When the instructor is satisfied with a man's capability of handling his machine and of turning out a fair amount of work, he assigns him permanently to a foreman who requires such service. The machine specialist then takes his place as a regular workman and receives regular day or piece work compensation. The same man, however, may apply again to the instructor for special training on some other machine; thus gradually fitting himself for a position as all-around machinist and tool-maker, with correspondingly higher compensation.

10 An arrangement of this kind entails no material hardship on anyone, gives many men an opportunity to rise to a higher plane of efficiency, automatically supplies the factory with capable machine specialists, and tends to attract to the factory men of ambition and stamina. This work might be further extended by giving to those who cannot sacrifice the temporary reduction of wages, an opportunity to receive their training during evening hours and on Saturday afternoons. This problem was outlined in my paper, A Plan to Provide for a Supply of Skilled Workmen (Transactions, vol. 28, p. 439).

TRAINING OF MECHANICS, FOREMEN, DESIGNERS, ETC.

11 Far more comprehensive in scope, and covering a longer period of time, must of course be the training of those who are to take positions as highly skilled mechanics and foremen, designers and engineers, superintendents and managers. The industries themselves must furnish this training, inasmuch as our school systems do not provide for it today, and very likely in the future will be able only to approach the full requirements. Mental training closely correlated with prac-

tical instruction may be gained by putting both under the sole charge of the factory management; or smaller factories may combine for joint classroom instruction; or the theoretical instruction may be delegated entirely to public school authorities, who could provide special classes for instruction alternate days or weeks. All three schemes are in operation today, and either will prove effective if properly managed, and if selected with reference to local conditions, size of factory and available personnel.

12 A bare outline of the system established by the General Electric Company, at West Lynn, which was fully treated in my former paper, may be of interest as showing how it has developed in the last three years, during which time about one hundred apprentices have graduated from the course.

REGULAR APPRENTICE TRAINING

13 Boys of at least 15 years of age, who have had a grammar school education or its equivalent, may be admitted on completion of a two months' trial period, to the regular apprentice course. It is largely contended by manufacturers that boys under 16 are not fit for trade training. A normally bright boy, however, unless he goes to high school, will usually be obliged to seek employment at 15, and it is better for him to be put immediately under systematic trade instruction. Naturally, the work at the beginning must be suited to the boy's immature physical as well as mental development, and boys lacking in physical strength will be accepted neither at 15 nor at 16 years of age.

14 The training for future tool and die makers, instrument makers and pattern makers, lasts four years, while iron, steel and brass molders, blacksmith and steam-fitter apprentices, who should be somewhat older and stronger, receive three years of training. The two months of trial are included in this period. Apprentices receive compensation, even during the trial period, at the rate of 8 cents per hour for the first six months, 10 cents for the second six months, 12 cents for the second year, 14 cents for the third year, and 16½ cents for the fourth year. Molder, blacksmith and steam-fitter apprentices, on the other hand, receive 10 and 12 cents per hour respectively for the first and second six months' periods, 14 cents for the second year, and 16½ cents for the third year. In either case satisfactory completion of the course entitles the graduate to a Certificate of Apprenticeship and a cash bonus of $100. The normal number of working hours is 55 per week.

15 The average compensation paid to graduated apprentices is \$2.75 per day, although some are started at \$3 a day immediately upon graduation. The significance of these figures is more fully appreciated when it is borne in mind that the young man of 21 years receiving such pay is only just beginning his life's work, with a solid preparation for marked future advancement.

16 All apprentices are obliged to spend from an hour and a half to two hours in the classrooms every day except Saturday, except during part of July and August, when instructors and apprentices may take their vacations. Classes meet during regular working hours, usually at the beginning or end of the half-day periods. Full compensation is paid during classroom hours. Retention on the course and the payment of the bonus are dependent on satisfactory work in the classroom as well as in the shop, and the standing in both is stated on the Certificate of Apprenticeship.

17 The classroom instruction is based on a grammar school education, and includes arithmetic, algebra, geometry and trigonometry, physics as it concerns simple machines, power transmission, strength of materials, machine design, magnetism and electricity, mechanical drawing, and jig and fixture design. For pattern-maker and molder apprentices an extended course in mechanical drawing is substituted for tool design. This instruction is practical, with constant reference to the work of the apprentices and to the usual factory problems, the aim being, above all else, to develop the ability to reason, and to foster a pride of vocation.

18 In no way is this stimulated more than by the daily practical talks of the superintendent of apprentices, who carries, so to speak, the factory into the classroom. The many answers offered by the apprentices to such a question as, "Why does a one-inch drill cut a larger hole in cast iron than in steel?" reveal their mental capacity and mechanical understanding and give the superintendent a splendid opportunity for driving home practical truths. The superintendent continues this kind of instruction in the apprentice training room. If he notices, for instance, that an apprentice uses an improperly ground tool, he calls a number of the boys to the blackboard and explains clearly by means of sketches what is wrong about the tool and how it should be sharpened.

THE APPRENTICE TRAINING ROOM

19 The training room is a special department for apprentices, a trade school in the factory, with this distinction, however, that all

work is commercial work selected solely for its instructive character. It had its inception in the belief that the apprentice should receive his initial training under the most favorable conditions and expert supervision. The very fact of this work being a part of the commercial output of the factory automatically insures a high standard of quality and quantity, and eliminates the false notions of these values usually found in purely educational trade schools. As a matter of record, the work of the apprentice is of a very high standard. Moreover, on work of a repetition character, the apprentices attain a speed of from two-thirds to three-quarters of that of the average workman, and a quality of work fully equal to the average; while on work generally classed as tool work, the apprentices very closely approach and sometimes even equal the work of the skilled journeyman.

20 The reports of the general inspection department show that rejected motor shafts, for instance, average only 2 per cent. although the permissible limits for the journal and other parts of the shaft are usually not more than 0.0005 in., and in any event not more than 0.001 in. Other work requiring accuracy to micrometer measurements is equally creditable to the apprentice training. Wherever possible, jigs made by the apprentices are not allowed to leave the training room unless the accuracy of the work has been proved by drilling or machining a part for which the jig was made. Several molds for various materials have been recently finished in the apprentice training room and the accuracy of the work proved not only by the pieces molded, but also by the fact that the parts of the various molds could be accurately assembled in the different permissible combinations.

21 Training rooms have been established for tool-maker and pattern-maker apprentices, occupying departments of about 15,000 sq. ft., and 4000 sq. ft. respectively. No training room has yet been organized for molder apprentices, of whom there are only a few, this part of the system being not yet very far developed. The training rooms are in charge of expert mechanics who act as assistant foremen to the superintendent of apprentices. One assistant takes care of about 25 apprentices in the pattern training room, and four assistants look after the business conduct of the machinist training room, with the instruction of about 130 apprentices. The small number of instructors and supervisors is explained by the arrangement under which the apprentices themselves, at various stages, act as instructors to those less advanced. In this way, not only is the instruction carried on with economy, but latent ability for executive

work is developed and the apprentices are taught self-reliance much more quickly than if their every step was directed by journeyman instructors; the aim being to train skilled and intelligent mechanics, as well as to develop on this basis industrial foremen.

22 It is indicative of the individual instruction afforded, that not infrequently a boy teacher has served a shorter period of apprenticeship than the pupil he instructs. No course has been laid out for the practical work; each apprentice being advanced as fast as is consistent with his individual capacity. He must have a fair understanding of his machine and be able to produce his work with commercial accuracy and a fair degree of speed before he can be advanced.

23 The company believes that inasmuch as it pays good apprentice wages and offers excellent training and educational advancement, it is justified in expecting a high standard of workmanship and of deportment. Accordingly, a rigid weeding-out process takes place throughout the course; more than 50 per cent of those serving the trial period are dropped at the end of two months and quite a few are discharged even after having signed the apprentice agreement. At first, a provision was made to send the apprentices to different departments in the factory, after about a year in the training room; later on, the time in the training room was extended to two years and the tendency now is to increase it to about three years before giving the apprentice a change to acquire additional experience. The advantages of this arrangement lie not only in the extended systematic training of the apprentices, but also in their better general supervision during the most impressionable period of their lives. At times, of course, apprentices in all stages of training are loaned to factory departments for a few days or weeks; on the other hand, some of those who have already progressed into the factory are brought back into the training room, if the quantity or quality of their work, or their deportment, necessitates such disciplinary measures.

24 At the present time there are over 200 trade apprentices at the Lynn Works, while 101 have already graduated. Of these 63 are now in the employ of the company, 8 serving as assistant foremen, 5 as inspectors and 12 as tool draftsmen, while the remainder work as skilled journeymen. Many of the latter, no doubt, will rise to positions of added responsibility during the next few years. The point is made clear to all apprentices, however, that a position as foreman or superintendent should not be the sole aim except for those with predominant executive ability. The percentage of graduates remaining with the company—in many respects a measure of the success of

the scheme—varies, but it has never dropped below 55 and at times has been over 80.

DRAFTSMAN APPRENTICES

25 No less encouraging are the results achieved with draftsman apprentices. Training for positions as draftsmen and designers is limited to young men with a complete high school education who pass examinations in algebra, plane geometry and elementary physics. It has been found necessary to introduce this examination on account of the great divergence in the curricula of high schools and the great difference in scholarships among graduates. Accepted applicants must serve a two months' trial period satisfactorily before being indentured for an apprenticeship of three years at 10 and 12 cents per hour respectively for the first and second six-month periods, fifteen cents per hour for the second year, and twenty cents for the third year. They receive then a cash bonus of $75 and a Certificate of Apprenticeship which states their efficiency in practical and in theoretical work.

26 Draftsman apprentices are obliged to attend classroom exercises about an hour and a half every day, except on Saturday and during part of July and August; and a considerable amount of home study is required. The educational work consists of advanced algebra, descriptive and analytic geometry, plane trigonometry, advanced physics, inorganic chemistry, strength of materials and machine design. Instruction is for the most part of college rank, and college text books are used entirely, but again the closest correlation with the practical work in the shop and drawing office is maintained.

27 Examinations are held three times a year and failure to pass in all subjects with at least 70 per cent necessitates the repetition of a fourteen weeks' period. A second failure in the same subjects, or repeated failures in different grades, result in the discontinuance of the whole course. This does not necessarily mean that the delinquents must leave the company, for under certain conditions they are permitted to continue on the shop apprentice course under a four years' agreement. A few have already made this adjustment.

28 Draftsman apprentices receive machine shop training during the first year and a half, and drafting instruction during the remainder of the three years' course. The machine shop work is given principally in the apprentice training room on account of special facilities for this instruction; a part of the time, however, is devoted to repair

work on machinery, and to tool work. The object is to give the future draftsman and designer an adequate insight into practical work so that he may appreciate in his designs the possibilities and limitations of the shop, and may, moreover, bear in mind the use of jigs and fixtures for economic manufacture on a large scale. The shop work, finally, inculcates in the young man an appreciation of the value of time and money such as he would not easily acquire without this training.

29 The work in the drawing office begins with a brief period of tracing, for the purpose of teaching the use of instruments, neatness, and the general arrangement of shop drawings; it continues on detail drafting and finishes with layout and design work. The high quality of the work of the apprentice is the natural consequence of the careful selection of applicants and the enforcement of a high standard of practical and educational achievement. Most of the young men are indeed a credit to the system.

30 The course for draftsman apprentices was originated about six years ago, but on a less ambitious plane. Grammar school graduates were then admitted for a four years' training, and no particular stress was laid on educational instruction. It was soon found, however, that in this way good tracers and detail draftsmen could be developed, but not high-grade draftsmen and designers. About four years ago a high school education was made an entrance condition, and a course of three years was offered. Soon after, class room instruction was added, extending but slightly beyond a review of the high school program. The apprentices who had been admitted under the less exacting requirements naturally fell behind and had to drop out, and the standard of the educational and drafting work was then gradually raised. Thirty-two apprentices have been graduated under these conditions, most of whom have become competent draftsmen, while a few have started on promising careers as designers.

31 Still the company was not satisfied with the scope of the course. It was recognized that the general standing of a draftsman and the standard of his work had everywhere deteriorated during the last decade, largely on account of the great influx of superficially prepared draftsmen. To develop draftsmen and designers of pronounced capacity and intelligence would dignify the work and regain full recognition of its potential importance. Moreover, the graduates of the machinist apprentice course proved to be capable of developing into competent tool and mechanial draftsmen, so that the demand for high-grade, intelligent designers became the more

pertinent. The final change in the course was therefore made, about a year ago, calling for an entrance examination, for educational work of collegiate grade, and for the extended training in shop work.

32 Ten draftsman apprentices are finishing their apprenticeship under the less exacting conditions, while twenty-four are receiving their training in the new course, and their progress augurs well for their future. In fact the training under the prevailing rigid system is expected to prove so effective that the privilege of a one year's post-graduate course in the various testing departments will be extended to all draftsman apprentices whose shop and office work has been very satisfactory and who have a standing of at least 85 per cent in all theoretical studies. These young men will then be eligible for important positions in engineering or commercial organizations.

33 Two other opportunities for systematic training have recently been opened to high school graduates, one for the preparation of testers and erectors of machinery, the other leading to a business career in a manufacturing establishment. These courses were instituted only within the last few months, and the results can only be foreshadowed.

TESTER AND ERECTOR APPRENTICES

34 Tester apprentices must pass an examination the same as draftsman apprentices, and the length of the two courses and the rates of compensation are identical. The practical work consists of about six months of testing motors or transformers, followed by about nine months of assembling and winding, the remaining year and nine months being devoted to a training in the various testing departments for meters and instruments, arc lamps, rectifiers, railway motors, and special electrical machinery, also turbines and turbo-generators. This work will be carefully supervised by a competent instructor, who will arrange for transfers from one class of work to another, and who will constantly keep the tester apprentices up to the required standard.

BUSINESS APPRENTICES

35 Business apprentices are recruited from high school graduates who have a leaning towards business activity, but not sufficiently high scholarship to pass the entrance examination and continue the educational work prescribed for the drafting and testing courses. These apprentices enter upon a two years' course at a compensation of

12 cents per hour for the first year and 15 cents for the second year, with a cash bonus of $50 at the successful termination of the course. They begin with six months of general stockkeeping, which acquaints them with the principal materials used in the factory, and leads to an appreciation of the value of these materials. Then follows a nine months' training on the writing of material lists and the compiling of stock reports. In this way the apprentices learn to read drawings and to make up lists of the kinds and amount of materials required for the production of one or several machines or machine parts delineated on drawings. They learn, furthermore, to calculate the losses that result from the cutting off of bars and the punching of various shaped parts. All this leads to accuracy and develops an interest in the value of stock which will show in the stockroom work of a more independent character which occupies most of the remaining nine months. These apprentices will also be given a training in shop clerical work, and this will be supplemented by instruction in arithmetic and geometry, the reading of drawings, and simple bookkeeping. This course has been instituted because the great value of proper stock keeping and factoiy accounting is recognized.

STUDENT COURSES

36 So far the plan outlined has dealt with methods of increasing the industrial efficiency of workmen and of preparing boys with a grammar or high school education for the trades and for semi-professional service. The company also seeks to provide, for young men of engineering collegiate training, an entrance into the industrial field which will lead to positions of scientific importance and administrative responsibility.

37 In common with other manufacturers the General Electric Company established many years ago, a "student course" providing for a two years' experience in the various testing departments of the Works. The young men were usually assigned to a testing department for a certain time, and were then more or less automatically transferred from one department to another until they had covered the whole course within the specified time. They very often did not take the work seriously enough, and in any event their chief aim was to get a general knowledge of as large a field as possible, rather than to acquire thoroughness in each specific field.

38 The company endeavored to eliminate these defects by organizing some three years ago a supervisory committee. This committee

met frequently with the students, and examined each one once or twice a year, in order to test his theoretical and applied technical knowledge, and his alertness for taking full advantage of the educational opportunities offered. In this way the committee was enabled to weed out some who showed no capacity for future responsible work, and to modify the course in each case to fit the individual student, and lead him into the field of his greatest probable usefulness. This arrangement unquestionably improved the general standing of the student training.

39 The real value of the committee's work, however, has been in the close contact of the members of the committee with several hundred students, and the opportunity to study carefully and specifically the bearing of the student training upon the work of the graduates in various positions inside and outside the factory organization. The committee soon recognized that while the training above described was, in general, a good preparation for those who elect positions in the selling organization, it did not give the right kind of experience to those who are to become designing, manufacturing and administrative engineers. This latter group needs a far more comprehensive knowledge of mechanical processes and a better understanding of the economic forces at work in a modern industrial establishment than can be acquired in the testing departments. With this in mind, the student course was put on a new basis a year and a half ago, and the work so far accomplished bears out the correctness of the premises.

40 In the present form the student course is divided into two parts, the so-called engineering and the commercial course. Admittance to either is dependent on a complete engineering college education, and almost invariably applicants must appear personally before the committee. The courses last two years and the compensation has been set at 20 cents per hour ($11.00 per week) for the first year, $22\frac{1}{2}$ cents per hour ($12.37) and 25 cents per hour ($13.75) respectively for the two halves of the second year. Without written agreement it is mutually understood that the student will give to the company two years of faithful service, and that the company, on the other hand, reserves the right to terminate the work of any student who at any time proves that he is not above the average either in capacity and special fitness or in good intentions. Aside from the direct advantage of such a rigid arrangement, is the added result of attracting to the course, as has already been demonstrated, high-grade young men, some even with one or two years of practical experience after graduation from college, who aspire to positions of prominence and realize

the value of a stiff training course with correspondingly good prospects. Even in busy times, when college graduates are in demand everywhere, young men with inherent capabilities will gravitate toward the Lynn course or any other course of equally high order.

41 Weekly evening lectures have been arranged, which all students are expected to attend, when the engineers and foremen of the company, as well as heads of the business departments, informally address the young men and stimulate a free and frank discussion of the subject under consideration. These lectures cover the principal materials of construction, important manufacturing processes, and the various lines of apparatus manufactured by the company. Occasionally talks dealing with business methods are interspersed. The complete program includes lectures on: (1) Iron foundry practice; (2) Steel foundry practice; (3) Pattern making; (4) Alloys and their properties; (5) Stockroom methods; (6) Forging; (7) Hardening; (8) Welding; (9) Factory cost keeping; (10) Tool steels; (11) Shapes of cutting tools; (12) Cutting speeds and feeds; (13) Piece-work rating; (14) Fibrous insulating materials; (15) Oils and varnishes; (16) Porcelain and molded compounds; (17) Shop bookkeeping; (18) Wires and cables; (19) Selection of materials in reference to design; (20) Drawing office methods; (21) Principal machine tools; (22) Care of and repairs to machinery; (23) Interchangeability of parts; (24) The essentials of production; (25) Punch press operation; (26) Die making; (27) Automatic machine processes; (28) Distribution of labor charges; (29) Requirements of accuracy in machine work; (30) Arc lamps; (31) Incandescent lamps; (32) Mercury lamps and rectifiers; (33) Lighting systems; (34) Factory building construction; (35) D. C. and A. C. motors; (36) Electrical features of motors; (37) Mechanical features of motors; (38) Motor drive of machine tools; (39) Labor report and pay roll; (40) Fan motors; (41) Industrial motor applications; (42) Railway motors; (43) Gears and pinions; (44) Avoidable factory losses; (45) Meters and instruments; (46) Standardization of instruments; (47) Sheet iron for electrical machinery; (48) Annealing of iron; (49) Transformers; (50) Testing of electrical machinery; (51) Shipping and receiving methods; (52) Steam turbines; (53) Valve gears and governors; (54) Buckets and bucket wheels; (55) Turbo Generators; (56) Turbine testing; (57) Wage payments; (58) Centrifugal compressors; (59) Gas motors; (60) The labor problem; (61) The reading of technical magazines; (62) Salesmanship; (63) Factory management.

42 Lectures are illustrated, by samples of materials and machines,

pictures, drawings and charts. They put the students in possession of up-to-date, practical information which they are not able to get from books or from outside sources. Lecturers and students alike have expressed their enjoyment of these evenings, which inculcate a certain class spirit which results in added ambition, increased loyalty to the employer and a broader conception of the work. This class spirit is discouraged, on the other hand, during the daily work, that the students may never forget that they must earn, as well as learn, in the service of their employer.

COMMERCIAL STUDENT COURSE

43 Commercial students spend about 2 months on meter and instrument testing, 2½ months on arc lamp testing and repairing, 1½ months on transformer winding and assembling, 4 months on transformer and rectifier testing, 2½ months on stationary and railway motor winding and assembling, 6 months on stationary and railway motor testing, and 5½ months on turbine testing or on other special assignments. They are stimulated to keep in touch with the latest engineering developments by carefully reading the technical magazines, and are shown the value of following up the advertisements in them as one means of getting acquainted with the general features of apparatus manufactured by competitors. Finally, the students are assisted in visiting power stations and installations, where they may see apparatus of various manufacturers and learn to observe keenly the essential points of operation.

44 Engineering students, on the other hand, receive most of their training in the machine shops, winding departments and drawing office, while the latter part of the course is devoted to testing, or to production, cost or other business activities as the capacity and inclination of the individual student may make advisable. These students are usually started on machine work in the apprentice training room, where they can receive instruction under the most favorable conditions for the first month or two. During this time, also, they can be closely watched, and here the first process of elimination takes place. In the next eight or nine months, students are assigned to various departments of the factory, in some of which they are put entirely on production work, in order that they may come under the influence of the intensity of production and may learn the possibilities of output on various machines, and in others they get experience in tool-making and repairs to machinery. Students who show an inclination toward heavy work are usually assigned to departments

in which the machining of turbines, street-car motors, and large motors in general, is done. Students inclined toward light work are, on the other hand, transferred to machine and tool-making departments in the arc lamp, meter and instrument or fan motor building. Some of the students spend a month or two in winding and insulating departments, again with particular reference to their future specialty.

45 For the following ten months, approximately, students are assigned to the drawing office, where they work first on detail drawings and then on assembly and layout work. Part of this time is devoted to tool designing, when students learn to design a drill jig or milling fixture or similar auxiliary apparatus for economic wholesale manufacture. The advantages of the drafting experience are obvious, especially for those who wish to become designing and manufacturing engineers. Inability to read drawings quickly, with an eye that sees the delineations grow into shape and form an achievement which can usually be gained only through a somewhat extended drafting experience, prevents many college-bred junior engineers from occupying positions of responsibiltiy in designing and manufacturing work. Drawing is the language of the engineer; it is equally useful to the one who supervises draftsmen and designers, or who interprets shop drawings to the mechanic and the foreman, and to the one who wishes to sell a piece of apparatus, when, by means of sketches he can illustrate the advantageous points of manufacture.

46 The remaining four or six months of the course are devoted to specific work leading to some definite occupation after graduation from the course. Thus, if the committee and the student agree that his future work should lie along manufacturing lines, he may act for a month or two as assistant to a department foreman, and acquire additional specialized shop experience. Another student, better fitted for scientific research or for general mathematical work, may receive a few months' experience on testing, especially of experimental apparatus, and may temporarily be assigned to an engineering department. A student who has shown particular aptitude for commercial work may be given some production and cost-accounting experience, while the future salesman is given an opportunity to spend the remainder of his course in various testing departments. A strong point is made of studying the development of each student, week by week, in order to train him along lines of his greatest capacity.

47 This purpose, as well as the desire to assist every student in the best way possible, and at the same time to exact from him a full

measure of service, has led to the appointment of a special instructor whose function it is to keep in almost daily touch with every student throughout the plant. The instructor endeavors to make the foremen of the departments, to whom students are assigned, sympathetic with the whole educational scheme, and to secure for the student work that will be especially helpful to him; he sees to it that every student works at the highest point of efficiency, and whenever he finds him doing his work in anything but the most approved fashion, or using wrongly sharpened tools, or fine feeds where coarse feeds are the proper thing, he explains and insists on remedial action. He, furthermore, tries to inculcate in the student a proper conception of his work, and to make him feel that while he must at all times give service, some one who is sympathetic stands ready to assist him.

48 The instructor makes a written report of the work of each student once a week, and presents it at the weekly meeting of the committee. The committee discusses every student in the light of the report, lays out his course for four weeks or four months ahead, as the case may permit, and talks personally to those of whom the instructor is not able to report favorably. An admonition is usually considered equivalent to placing the student on a few weeks' probation, with the understanding that he will be dropped without hesitation if at the end of the probation period a decided improvement cannot be reported. The committee, furthermore, interviews new applicants, and selects those for the engineering or commercial course.

49 A competent instructor with testing experience will soon be appointed to follow the commercial students through their course, unless the commercial course is abandoned on the theory that students with a training such as the engineering course offers will be better salesmen than if they had testing experience alone.

50 All in all, it would seem that the student training has been laid out on a broad basis, with due regard to the interests of the student as well as those of the company; and it is fair to expect that this training will develop a body of theoretically and practically educated young men, who, on account of their knowledge, their broad conception of things, and their sympathetic outlook, are in line for positions of the highest order either with the company or with other concerns.

51 A definite policy, a sympathetic following up of the students, insistence upon a high standard of work, and a sympathetic oversight of the students by a committee of competent men, are the distinguishing features of the Lynn student courses.

52 The educational policy of the Lynn Works provides systematic training suitable to all classes of people. The unskilled worker without particular education receives a training adequate to his immediate needs; the grammar school boy is initiated into the trades on the basis of a four years' course with educational instruction of a high school character; the high school graduate is trained for semi-professional service of a technical or business nature, on the basis of a three years' course with educational instruction of collegiate grade; and the college graduate is prepared for professional service of the highest order, on the basis of a two years' training of which the educational instruction assumes the character of a post-graduate college course. Obviously, there are other ways of obtaining these results. Coöperative efforts between the engineering college and the factory, for instance, may be substituted for college instruction, followed hy practical training through a student course. (See address before the American Institute of Electrical Engineers, June 1908, A Method of Training Engineers.) Educationally, psychologically and economically, the scheme is sound.

53 There are three main problems that enter into production,—the machine problem, the material problem, and the man problem. It is clear that the man problem is the most difficult of solution but also the most important in competitive activity. It must be approached in the same scientific manner and with the same painstaking concentration of effort that is today applied to the other two problems. The training of men must be the key-note of our industrial expansion. At least in the larger industrial establishments, this calls for a new type of engineer who might appropriately be known as the economic engineer.

DISCUSSION

THE HIGH-PRESSURE FIRE-SERVICE PUMPS OF MANHATTAN BOROUGH, CITY OF NEW YORK

BY PROF. R. C. CARPENTER, PUBLISHED IN THE JOURNAL FOR SEPTEMBER

ABSTRACT OF PAPER

This paper describes the high-pressure pumping systems installed for fire service in the city of New York and gives the results of tests of the pumping machinery. There are two pumping stations for the system located in different parts of the city, deriving their supply from the Croton system, although sea water can be used in an emergency. There are five pumping units in each station consisting of Allis-Chalmers five-stage centrifugal pumps driven by induction motors. The pumps each have a capacity of 3000 gal. per min. and a delivery pressure of 300 lb. per sq. in. The distribution system covers a large section of the city between Chambers and Twenty-third Streets and is designed for the high pressure that must be met in service. In the tests the quantity of water discharged was measured by venturi meter. Tests were made of the pumps when running together and of certain of the pumps running singly under different discharge pressures. The efficiency of the pump tested singly in one of the stations under normal conditions varied from 70 to 77 per cent, and of the pump tested in the other station, under the same conditions, from 76 to 79 per cent. The pumps were put to a crucial test on January 7, 8 and 9, 1909, when brought into service for five simultaneous fires. Seven pumps were operated, delivering 35,500 gal. per min. against an average pressure of 225 lb. at the pumps and 205 lb. at the hydrants. The total pumpage was 14,095,000 gal., and the current used 81,450 kw-hr., costing $1222.

DISCUSSION AT NEW YORK

PROF. GEORGE F. SEVER.[1] The electrical features of this installation are of much interest but the reasons for selecting that system which is now in operation should be given. In the discussion of this problem both alternating and direct-current power were considered for the operation of the motor-driven pumps, and alternating-current power was decided upon. The reasons for such selection I have noted herewith:

[1] Professor of Electrical Engineering, Columbia University.

a Absolute simplicity, that being the key-note of the electrical end of this power installation.

b The absence of all commutating apparatus and brushes.

c Induction motors provide very quick starting when it is necessary to operate the station on a fire signal.

d There is less expense for copper in the distribution system to insure continuity of service.

e The induction motor is a less expensive apparatus than the direct-current motor.

f With the induction motor there are absolutely no exposed live circuits in the station, as there might be with a direct-current apparatus. The final decision was for 3-phase service at 6600 volts and 25 cycles. It was decided that it would not be desirable to establish a power house to be operated by the city because it would be a municipal plant.

2 In order to insure continuity of service there is brought to each pumping station an independent feeder from each of the two Waterside stations of the New York Edison Company. There is also brought to each pumping station an independent feeder from the nearest substation of the New York Edison Company, as follows: to the Gansevoort Street station two feeders from the Horatio Street substation, and to the Oliver Street station two feeders from the Duane Street station of the company. Hence there are really four independent sources of power supply for each pumping station, assuring practically no possibility of shutdown.

3 The contract for electric power for the Manhattan station was let to the New York Edison Company. This contract provides for two payments, the first for a reservation of 3250 kw. capacity, of generating, distributing and controlling apparatus, available at either pumping station at an instant's notice, or practically without any notice at all. Thus four pumps can be thrown on with absolutely no notice to the New York Edison Company that they are to be used. For that reservation, and care and maintenance of the whole distributing system, the city pays about $63,000 per year, and the city also pays one and one-half cents per kw-hr. for all high-tension power used in each station.

4 There is also another interesting stipulation in the contract, which may be of interest to the engineers as it provides for the protection of the city. This stipulation is as follows: "If the contractor, under the terms of this contract, shall fail to maintain and deliver

a continuous and uninterrupted supply of electric power when required, the contractors shall and will pay to the city the sum of five hundred dollars per minute for each minute's interruption or delay of electric power supply after the power has been interrupted or delayed for three consecutive minutes." So, if they cannot deliver power after an interruption of three minutes, immediately a charge of $500 per min. is imposed and is deducted from the bills which the New York Edison Company renders.

5 The operation of both these stations is extremely simple. The handle of the oil switch is turned, throwing the 6600 volts directly on the stator of the motor. By turning a hand wheel, the motor is brought up to speed in less than 33 sec., and in starting the current is not supposed to exceed 150 per cent of the full-load current, which is 64 amperes. As far as I have observed the operation of the station, there has been absolutely no trouble from the electrical end, no trouble with the feeder system, and none with the motors, and I think the City of New York has two plants which will give them for many years to come absolutely no trouble whatsoever.

Wm. M. White. The paper deals with questions in which I am directly interested. The methods employed in making the tests were probably the best that could have been selected. There is probably no more accurate method of determining the quantity of water delivered by a pump than by the venturi meter, especially when in the hands of an expert who is familiar with its workings. The venturi meter, as Professor Carpenter says, has been used for a number of years; it has been tested in various ways and proved to give accurate results. The power delivered to the pumps can be most carefully obtained by electrical instruments.

2 The writer accepts without question the various efficiencies obtained and presented by the author, who states, calling attention to the variation in efficiencies obtained, that the individual observations do not agree as closely as he would like. I do not think Professor Carpenter should offer any apology as the results seem to agree very closely, and certainly are as accurate as are generally obtained on work of this kind. The efficiencies obtained on these pumps, though not the highest that have been obtained, are as high as is usual for similar conditions of head, capacity and speed. The designers of the pumps deserve credit for the performance shown by the pumps.

3 I am at a loss to find a reason for the variation in efficiencies of the pumps, as mentioned in Par. 65, where it is stated that individual

pumps delivering water into a main singly show greater efficiency than the same pumps delivering together into a single main. I assume, of course, that the variation in efficiency refers to the pumps when they are delivering exactly the same quantity against the same head at the same speed, whether working singly or in parallel. In the normal operation of pumps, it would be a fact that when one pump was operating from a suction main to a discharge main, the efficiency of that pump would be different from what it would be when working with another pump from the same suction main and discharging into the same discharge main, because the two pumps would usually be working against a higher head than when a pump was working singly. The increased head on the pumps would mean a decrease of capacity, and the increase of power demanded by two motors instead of one would mean a slight increase in line loss, which would again slightly decrease the speed and slightly change the conditions of operation for two pumps over that which would exist when one pump only was in operation. Of course, under these conditions, the two pumps would show different efficiencies, because the efficiency curve of a pump varies as its capacity and head.

4 I do not believe, however, that this is the condition to which Professor Carpenter refers. I assume that he has corrected for this difference, and has obtained from two pumps working in parallel the same capacities, heads and speeds as though one pump were in operation, and that under this latter condition he finds the difference in efficiency in the two pumps. If this be a fact, it is the most important point brought out from a designer's point of view.

5 I am at this time attempting to duplicate the conditions, to see whether the efficiencies are different under the same conditions of capacity, head and speed, as mentioned by Professor Carpenter.

George L. Fowler. A number of years ago I was associated with Joseph Edwards, who at that time had the contract for excavating the ship channel in New York Harbor, probably one of the first, if not the first, very large hydraulic engineering projects successfully accomplished by the contractor and to the satisfaction of the Government.

2 The ship channel leading from the Narrows down to Sandy Hook and out to sea, is about 15 miles long, and runs almost due south first, turning to nearly due east before reaching Sandy Hook, and passing through Gedney Channel to the sea. Cutting across it is

the Swash Channel, not used by any deep-draft boats. When the work was undertaken New York Harbor was shoal at two points on the Gedney Channel and the ship channel, where the water depth was a little less than 24 ft. The Government had a survey made and an estimate of costs based on material actually removed by the ordinary methods of dredging. Through the open space from Sandy Hook to Coney Island the whole lower bay is subject to all the winds coming in from the Atlantic on the east and across Raritan Bay, so that the water is nearly always rough. Two contractors had attempted the work by ordinary bucket dredging and both had failed.

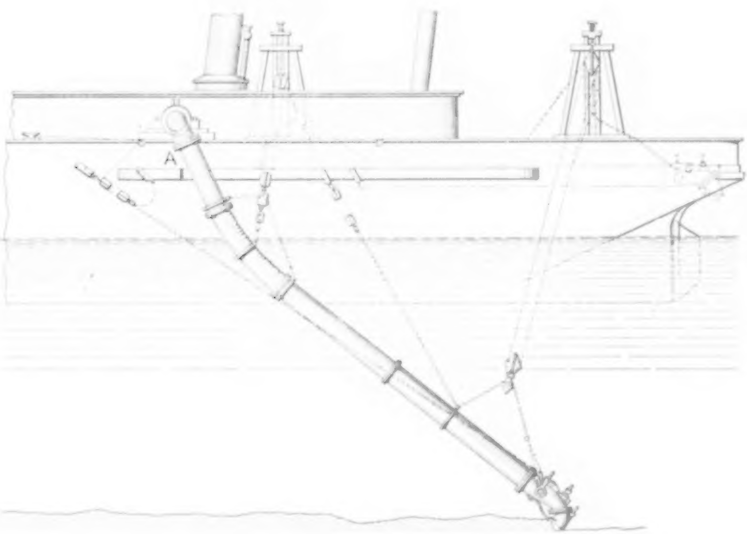

FIG. 1 HYDRAULIC DREDGER FOR DEEPENING SHIP CHANNELS

3 In the ship channel the material was sand and sedimentary clay, lying over hard sand; in the Gedney Channel it was gravel, shell and sand, for two feet overlying hard shingle. Hydraulic dredging was specially suited for this kind of work, and many kinds of material were removed from the channel besides the ordinary silt.

4 Three sea-going vessels were built for this work by the Joseph Edwards Company: the Reliance, the Advance, and the Mt. Waldo. Fig. 1 shows the general arrangement of the ships. At A is the long drag aft, where the pipe goes into the vessel and where the pumps are located, each driven by a 192-h.p. engine at 178 r.p.m. The suction and delivery pipes were 15 in. in diameter, with a shell of 40 in. The

pumps delivered 10,000 gal. per min. at a velocity of 1100 ft. The efficiency was thus between 65 and 70 per cent, although in later tests made by the Government, when nothing but water passed through the pipes, the efficiency rose to as high as 80 per cent.

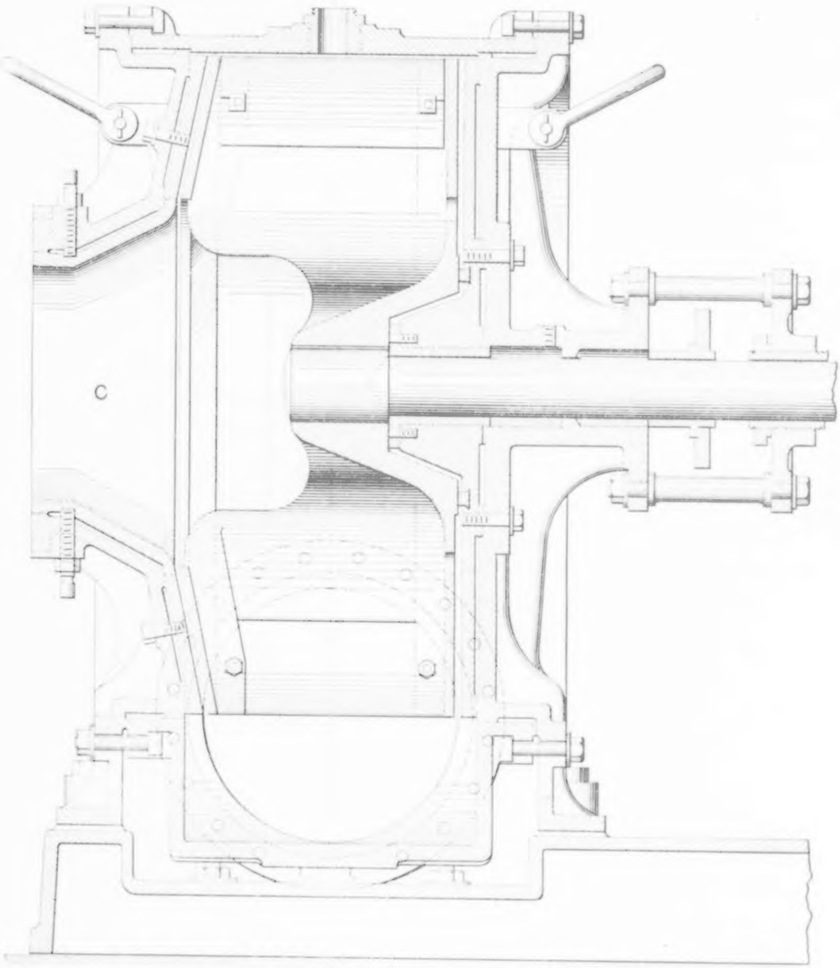

FIG. 2 SECTIONAL VIEW OF CENTRIFUGAL PUMP FOR DREDGING

5 The shoe used is a hook that drags along the bottom, chains being fastened to the vessel for this purpose. The vessel never

stopped from morning to night, simply running out to sea, dumping, and coming back again to work.

6 At the point *L*, Fig. 3, was the heavy shoe that served to dig into the mud and gravel. At *O* was a butterfly valve, kept open all the time to admit water above the drag to mix with the material raised. At the bottom *K* was another valve which could be opened in an emergency, in case not enough water was admitted at *O*.

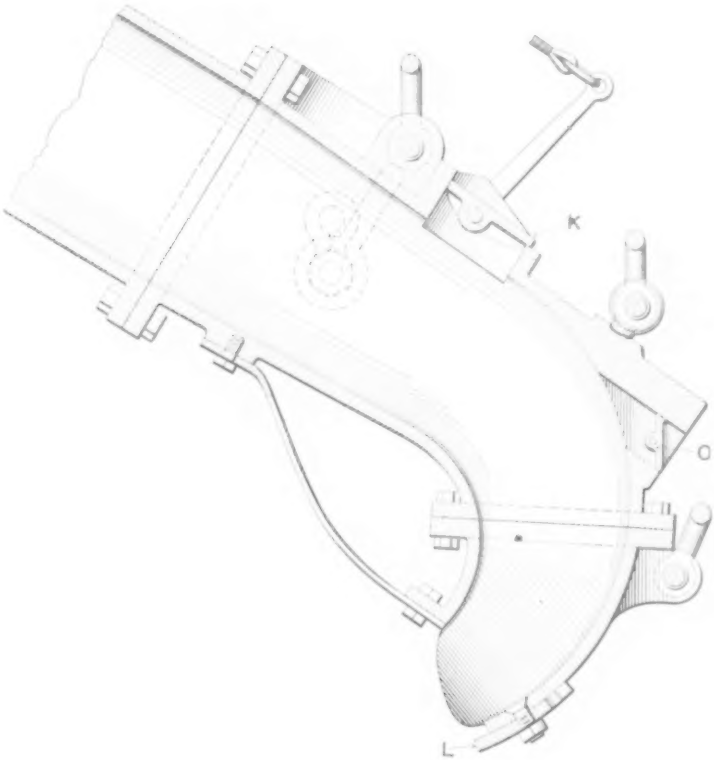

Fig. 3 Detail of End of Suction Line

7 The pump itself was of a plain centrifugal type, 40 in. in diameter, with vanes cut away at the center, as shown in Fig. 3. Because of this arrangement, the material would come in at *C* and out of the vanes at the discharge, without damaging the pump when heavy substances were drawn in. The three vanes were made with wings

bolted on, and accessible from both sides. The thrust was taken up by the bearing at *T*, the nuts marked *m* being screwed into a head carried by the bars *O*, bringing the thrust plates at the point *i*. The reason for threading the nut *m* was to adjust it to the vanes in proper relative position to the sides of the pump. That is a simple construction maintained ever since, with the exception that ball bearings are now used.

8 Although the pumps were originally intended to take water and other loose material, such as sand and gravel, they proved capable of lifting practically anything that came in their way. The three following specimens are interesting as showing the pumps' lifting power:

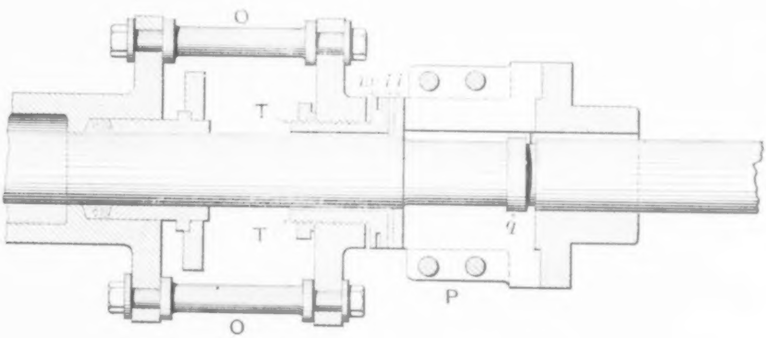

FIG. 4 DETAIL OF THRUST BEARING OF PUMP

A piece of shaft weighing 70 lb. raised and passed by a 15-in. dredging pump; improvement of New York Harbor, Steamer Reliance.

A piece of tree root raised and passed by a 12-in. pump from 14 ft. of water at Miami, Fla.; Florida East Coast Railway Company improvements.

A piece of pig iron measuring $11\frac{1}{2}$ in. by $4\frac{3}{4}$ in. by $3\frac{1}{4}$ in. and weighing 35 lb. raised and passed by an 8-in. special cataract wrecking-pump from 15 ft. of water from the wreck of a canal boat sunk at Puas Dock, Yonkers, N. Y., by the Baxter Wrecking Company, New York.

9 For hydraulic dredging, the Government pays by the scow load and gets what is excavated. In ordinary hydraulic dredging, like that in the ship channel, about 15 per cent of the pump discharge was solid matter. About 40 per cent in excess of the amount deposited

in the bins went overboard with the overflow, and was carried out to the flats at the sides by the cross currents, which also carried the loose material stirred up by the drag. The result was that the Government obtained an excavation about 70 per cent in excess of what would have been obtained had all of the material removed from the bottom been caught in the bins. This, of course, greatly reduced the actual cost of the excavation. For example: the last contract made on the ship channel was at the rate of 16⅞ cents per yard, while with the allowance indicated, above the actual cost per yard—channel measurement—it was about 11 cents.

10 As for the time of loading, some records indicate that this ship, 157 ft. long and with a capacity of 650 cu. yd., was loaded in 48 min.; there are also records of its being loaded at the rate of 16 cu. yd. per min., of solid matter placed in the bins; and records of its taking out to sea nearly 4000 cu. yd. per day. The vessel was worked in all kinds of weather, even when tackles had to be used to board her; and yet the ship was taking her load steadily. Except in the case of an actual breakdown the work could be carried on for 16 hr. per day.

John H. Norris. In a pumping plant of the character described, this type of equipment seems in the present state of the art the most suitable that could have been selected. I would like, in this connection, to call attention to another type of installation for service of this kind, though not on so large a scale, which appeals to me as being more desirable than the electric driven centrifugal pumping plant taking its power from the public utilities company.

2 At Coney Island was installed the first plant operated by the City of New York for fire protection by means of water delivered into mains under high pressure, with the idea of taking care of a restricted area where there was great danger from fire.

3 This plant consists of three 150-h.p. three-cylinder, vertical gas engines direct-connected to triplex pumps, each unit capable of pumping 1500 gal. per min. against a pressure of 150 lb. These engines take their fuel from the mains of the local gas company and can be arranged if necessary to run on gasolene. They are installed in a building on city property and are arranged to take their water supply from the city mains or from Coney Island Creek, within 50 ft. of the pumping station. The engines are started with compressed air, and the three units can be started up in less than three minutes. On every occasion they have been found ready for service whenever

the demand was made upon them. The cost of this pumping station was as follows:

Building	$10,000	
Equipment	37,000	
		$47,000
The annual operating expenses are:		
Labor		$13,140.00
Supplies and Repairs		897.27
Fuel		150.00

4 By comparing the foregoing figures it will be evident that for service smaller than is required in the City of New York, the gas-engine-operated triplex pump gives an economical equipment that can be allowed to stand idle for any length of time and yet be ready for instant service.

5 New York City pays the New York Edison Company an annual charge of $90,000 for the privilege of calling for sufficient current to operate the equipment at any time. This item capitalized at 5 per cent would pay for a good-sized gas-engine plant.

6 The following data were taken from the capacity tests of the Coney Island units:

Duration of test	14	hr.
Average piston speed of pump	90.3	ft. per. min.
Total head pumped against	156.5	lb.
Average pump horsepower for each unit	142.2	h.p.
Average gas consumed per hour for the 3 units	8914.0	ft.
Average gallons per minute	4512.0	
Slip of pump	3.45	per cent
Average efficiency of pumps	82.00	per cent

J. R. Bibbins. Although Professor Carpenter's paper deals primarily with multistage pumps, I wish to direct attention to the question of motive power, upon which the success or failure of the system practically depends. We have seen excellent examples of two systems diametrically opposed in regard to power supply—the electrical and the gas-driven system. Under certain conditions, both are extremely serviceable. The first high-pressure installation on a large scale, in this country, was the gas-driven system at Philadelphia. Although I have not had an opportunity to follow the results of that station for the past two or three years, the results obtained and published for

the first year or so showed that such a system of gas-driven pumps merits every consideration.

2 First as to the security of power supply: In Philadelphia the Delaware Avenue station receives its gas supply directly from a 24-in. trunk main running between two very large gas holders, located in different parts of the city. Roughly, the pipe line measures four miles in length, its capacity constituting a considerable reserve in itself, if both the holders were unavailable. There is no intermediary apparatus whatever between the pipe line and the engine; that is the plant may draw directly on these two large holders of several million cubic feet capacity. This constitutes a very safe and reliable source of motive power which can hardly be paralleled except, perhaps, by the situation in the New York electric service, where there are so many stations to draw from.

3 In this connection, I would like to ask whether it is at present possible to utilize the storage battery capacity in the various sub-stations for reserve service at the high-pressure pumping station? It is stated that the storage batteries are available for reserve in emergencies, such as discontinuance of the main high-tension current supply. I am under the impression that an inverted rotary requires a direct-driven exciter to maintain a definite frequency and prevent racing. Without special controlling apparatus, this inversion would be impossible in the ordinary sub-station equipment. Possibly special provision has been made in the New York systems, in which case, the security of power supply is certainly beyond criticism. In other words, would it be possible to invert the synchronous converters on short notice?

4 Second, quick starting: It seems to be a fact that a large part of the minimum time required for the starting of a fire-service station is consumed in the operation of the motor-driven by-pass valves. In Philadelphia these valves are operated from an independent supply, as in New York, and at least fifteen seconds are required to close them; whereas the engines are brought up to speed within half a minute from the time the signal is given, the remaining time being usually consumed in closing this motor-driven valve.

5 The various tests of the Philadelphia plant showed that each of the units could be readily put on the line in well under one minute. It is an interesting fact that the original underwriters' tests specified the time limit as twelve minutes for the starting of the first three units, whereas the whole station can be started in that time, and has been started in seven minutes.

6 During the 36 days of preliminary service trials of the Philadelphia station, out of one hundred alarms given, only four misses were made in getting any of the eleven units started. In not a single instance has the station, as a whole, failed to respond to the service, at least during the period over which my observation extended. This has been accomplished with the regular operating force of three men.

7 Third, in regard to the cost of service at Philadelphia: The only data on a large fire available, are those of the fire in the Coates Publishing House, which lasted about nineteen hours. The average cost for pumping was about six cents per thousand gallons, including gas, wages and supplies. The cost of the large East Side service, cited in the paper, is about nine cents for power alone, and I think this does not include the readiness-to-serve factor. On the other hand, it is patent that the cost of service in either the gas or the electrical station is relatively unimportant. The main desideratum is reliability.

8 Finally, I desire to advance an argument for the development of a new type of pump unit, namely, a high-speed gas-driven centrifugal pump. Some time ago, in connection with water-works service, I found great difficulty, even with the present high-speed single-acting gas engine, in matching engine speeds with those required in centrifugal pump work. However, for the pressure necessary in water-works practice, about 125 lb., one or two sizes of engines were found to be directly applicable to multistage pumps, with fair proportion of parts and good efficiencies. It seems possible to adopt a modified type of gas engine which would permit the direct connection mentioned.

9 This modification would naturally follow along lines of short stroke and high piston speeds with perhaps four cylinders. The engines at Philadelphia were designed with a piston speed of but 730 ft. per min. with a 22-in. stroke. This might be increased to 1000 ft. per min. without exceeding present-day limits, especially for units designed for occasional service. Such a unit would find immediate application in many industries and would combine the high economy of the gas engine with the simplicity of the centrifugal pump. The efficiencies shown by Professor Carpenter place the centrifugal pump in a position of closest competition with reciprocating pumping units.

J. J. Brown. I recently made a series of tests on three 6-in., 8-stage centrifugal pumps, each designed for 1000 gal. per min. and 560 lb. pressure at 1200 r.p.m. One of these pumps gave an efficiency from wire to water of 71 per cent, or a pump efficiency of 76 per cent. I

regret that Professor Carpenter did not give the results of his tests on the New York fire-service pumps at lower capacities. All of the tests were made at capacities considerably in excess of that for which the pumps were designed and they apparently show their best efficiency at approximately 25 per cent over the normal rating. This increased efficiency at excess capacity seems to be apparent in several recent tests made on high-lift centrifugal pumps. The 8-stage machines previously referred to give their best efficiency at 1300 gal., or about 30 per cent over rating.

2 Mr. White has raised a question as to the difference in efficiency between the New York fire-service pumps working in multiple and as separate units. I think this is occasioned by the variation in capacity of the pumps when working together on a common suction and discharge line. I have found it rather difficult to balance two centrifugal pumps on a common discharge, and pitot tube tests indicate in almost every case a considerable difference between the amounts of water handled by the individual units under these conditions.

3 I have in mind one installation on fire service, where the pumps were called upon to deliver against the maximum pressure for which they were designed and it was only with considerable difficulty that we were able to cut in additional units. I think that if venturi meters or pitot tubes had been placed on the discharge of each of the five pumps when they were working in multiple, a difference in capacity of the several units would have been shown, which would account for the difference in efficiency observed when the pumps were working individually and not in multiple.

George A. Orrok. At the time of the award of contract for these fire pumps, the New York Edison Company was obtaining proposals for centrifugal feed pumps—a somewhat similar service—and eight 1000-gal. 300-lb. pressure fire-stage pumps were purchased. There was no attempt to obtain a high guarantee for efficiency, but the builders did state that under the above conditions an efficiency of 65 to 68 per cent would be obtained. These pumps were of the Jager type and under test showed an efficiency of about 68 per cent.

2 Fig. 5 shows that the high-pressure fire-service pumps are of the Kugel-Gelpke type and should be a trifle more efficient because of smaller friction and leakage. Seventy-one per cent seemed a very high efficiency and many doubts were expressed regarding the fulfillment of the guarantees. The extreme figure of 79 per cent obtained is probably the result of careful design and extra good shop

work and I believe has not been excelled. That this figure came as a surprise may be explained by the fact that most centrifugal pumps are stock pumps and not specially designed for the work they have to do. Pump manufacturers have been more concerned in getting a line of patterns that will suit standard conditions than in developing a line of pumps and system of patterns capable of doing the best work.

3 As a centrifugal pump is a reversed mixed-flow or Francis reaction turbine, similar care in design and construction would probably give efficiencies similar to those of the best makes of reaction turbines, which approximate 90 per cent.

Frederick Ray. The difference in efficiency of the units operated individually from that obtained when several were operated in parallel might be due to the different rates of flow through the venturi meters under the two conditions. With one pump operating, this flow would be low and the mercury column reading would be but slightly over an inch, so that with a given error of observation the percentage of error would be much greater than with two or three pumps discharging through the same meter.

2 Professor Carpenter here replying that the pipe connecting the two meters was open all the time, Mr. Ray continuing said:

3 This would equalize the flow in the meters when the whole station was running, so that the mercury column reading would be about 6¼ times the reading with one pump. It has not been my experience that parallel operation of a number of pumps has any tendency to decrease or otherwise change the efficiency obtained when operated individually. The efficiency should be the same, and in this case, as the pressures were taken at each pump, any losses in the piping system due to parallel operation would be external to the gages and would not show in the calculations. If the pressure had been taken at the discharge of the whole system, losses in the piping would affect the results.

4 Many pumps are running under similar conditions, at the efficiencies given. I have myself obtained efficiencies of 79 or 80 per cent and higher, but I do not rely as much on them as on some a little lower. I am now testing a 6-in., 2-stage underwriter pump, having a normal capacity of 500 gal. per min. against 100 lb. pressure, which has developed a maximum efficiency of 73 per cent.

5 I think the centrifugal pump is the ideal one for fire service, not only on account of its simplicity and reliability, but also on account of its characteristic increase in capacity as the pressure is

reduced. Thus, the 500-gal. underwriter pump referred to will discharge 870 gal. per min. at 60 lb., or enough for four streams at this pressure. It will give three streams at 90 lb., two streams at 110 lb. and one at 117 lb.—all at constant speed without any regulation whatever.

6 The City of Toronto has recently issued specifications for centrifugal pumps for their general municipal water supply, among which are several fire pumps capable of discharging against 300 lb. pressure. These pumps, however, are to be equipped with variable-speed induction motors, the pressure regulation being obtained by speed variation. This is superior to throttling regulation from the standpoint of current economy and in the case of the New York installation a considerable saving could be made by this means, as most of the fires can be handled with 200 lb. pressure or less.

H. Y. Haden. A somewhat unusual result is obtained from this type of pump, for as the total head continues to increase beyond a certain point, the capacity falls off, with the result that the capacity curve, as given in Fig. 7, shows a backward tendency. It will be interesting to get the explanation of this.

2 There is unquestionably a large field in fire protection for steam-turbine-driven centrifugal pumps, and it is to be hoped that the Fire Underwriters will officially accept this type of fire protection unit. I believe that a properly designed centrifugal pump, for high speeds and of few stages, can be used to great advantage when direct-connected to high-speed turbines.

Thomas J. Gannon.[1] It was decided to use electricity as power for the pumping stations, because the first cost of installation and the yearly cost of operation and maintenance and fixed charges were estimated to be lower, taking into account the intermittent service. The construction and operation of a steam plant were entirely out of consideration and the choice lay between gas-engine-driven and electric-driven pumps receiving power from outside sources.

2 It was estimated that gas operation of plants equal in capacity to the present electrically driven plants, would involve a fixed charge of $50,000 a year, in addition to the cost of the gas actually consumed. The question as to who should build and maintain

[1] Engineer, Dept. Water Supply, Electricity and Gas, Manhattan Borough, New York.

the necessary large gas mains, the cost of which would approximate a million dollars, was not definitely settled. That the cost of a gas-engine-driven pumping plant would have been approximately double, both for machinery, building and area of land to be purchased, is borne out by the actual cost of the installations in Manhattan and at Coney Island.

3 The capacity of the gas-operated Coney Island plant is 4500 gal. of water per min. against a head of 150 lb. per sq. in. The cost of the machinery is approximately $37,000 and the cost of the building approximately $10,000. The combined capacity of the two pumping plants in the Borough of Manhattan, as originally laid out, was 30,000 gal. per min. against a head of 300 lb., with provision in each station for three additional pumping units of a capacity of 3000 gal. each, making a total combined capacity of 48,000 gal. per min. against 300 lb. pressure. On actual test, however, the capacity of the pumps was approximately 20 per cent greater than the designed capacity.

4 Furthermore, the flexibility of this type of pump permits of an increased discharge at lower pressures, which gives a capacity of approximately 5500 to 5600 gal. per min. for pressures between 150 and 200 lb., or a combined total capacity of 55,000 gal. per min. against 200 lb. pressure. This corresponds to the pressure at which the station is operated for most fires. In other words, the water horsepower of one plant, as compared with the other, is approximately in the ratio of 20 to 1.

5 The first cost of installation of the gas-engine-driven plant is therefore more than double the first cost of installation of an electrically driven plant, in the city of New York. The cost of each of the two Manhattan pumping stations complete, exclusive of land, was practically $240,000.

6 The high-pressure fire-service pumping stations went into official operation on July 6, 1908. It was at first decided to put the stations in service only when called on by the fire department, and up to and including November 20, 1908, the pumping stations were called upon to go into actual service for but 17 fires. On that date, the method of operation was amended so that the pumping stations are put in service in response to every alarm in the high-pressure district, and continue in operation awaiting instructions from the fire department. Under this system, from November 20 to December 31, 1908, the pumps responded to 116 first alarms. From the best available information, water was used in 55 instances, making a

total of 72 fires for which the high-pressure service had been used up to that date.

7 To insure readiness for service at all times, daily tests are made, of at least half an hour's duration, unless the station has been in actual operation during the preceding 24 hours.

8 During the first quarter of 1909 the number of alarms received was 239, and water was taken from the station for 125 actual fires. The total amount of water pumped was 17,840,000 gal., and 145,900 kw-hr. was consumed. It was on January 7, 8 and 9 of this quarter that the three large simultaneous fires mentioned in Par. 75, occurred, for which over 14,000,000 gal. of water was pumped, leaving about 3,800,000 gal. for the balance of actual fires occurring during the quarter. For these three simultaneous fires more than 81,000 kw-hr. was consumed while the total consumption of power for the quarter for all fires and testing purposes was but 145,900 kw-hr.

9 As to why a pump running singly develops a higher efficiency than when running in conjunction with several others, it is observed that pumps of the same type do not necessarily develop their best efficiency at the same speed and pressure. The pump running singly will naturally develop a pressure which corresponds to its own design, but when working in multiple, it will have to adjust itself to the common pressure.

10 As to reliability I have neither seen nor heard of any time when any one of the ten pumps installed in the Borough of Manhattan has failed to respond instantly when called on for service and to develop the full pressure on the system within one minute's time. At no time in service have the pumps shut down of their own accord.

HENRY B. MACHEN.[1] Among the many difficulties encountered during the construction of the distribution system, perhaps the greatest was that due to the congested sub-surface of the street, which was a source of continual extra expense to the contractor, and of worry to the man in charge of selecting the location for the excavation of the trench.

2 The intersection of Sixth Avenue and Fourteenth Street may be cited as an example, since complete notes are available, due to the station excavation for the Hudson Tunnels. Here there were nine gas mains east and west, and nine north and south, belonging to

[1] Engineer, Dept. Water Supply, Electricity and Gas, Manhattan Borough, New York.

four different companies; two water mains in each direction; sewers and their connections on each side of the street; five Edison duct lines, and five duct lines with large manholes belonging to the Consolidated Telegraph Subway Company or the Empire City Subway Company; the conduits and banks of ducts of the Fourteenth Street and the Sixth Avenue trolleys; and lastly, the columns of the elevated railroad with their deep foundations.

3 Through this network the high-pressure main had to be so laid that the construction of the Sixth Avenue tunnel would not require it to be relaid. The excavation was carried on by tunneling, with here and there an opening through which the earth could be hoisted, using a pail let down by a rope. The pipe was lowered into the trench some distance up the street and pulled through, piece by piece, inspection of the running of the joint and caulking being almost impossible, since the space admitted but one man at a time after the pipe had been hauled in.

4 This condition existed at nearly all intersections of the main thoroughfares, such as Broadway, Sixth Avenue, Fifth Avenue, the Bowery, etc., and accounts for the high cost of laying the mains, averaging about $11 per ft. complete.

5 The second great difficulty encountered was in obtaining the prescribed test, which called for 450 lb. pressure per sq. in. to be held for 10 min., during which time the leakage was measured.

6 The system contained about 40,000 castings, 30,000 being straight pipe, tested at the foundry to 650 lb. The specials were not tested. All these castings, as already stated, were tested in the ground to 450 lb., the mains being under pressure in sections about one block long, between gates.

7 During the eighteen months the system has been in service, there have been but three breaks in the mains, all three in castings which had been subjected to the foundry test of 650 lb., two breaking at 150 lb. and the third at 300 lb. pressure.

8 To overcome the danger should a break occur during a fire, the proposed extensions to the distribution system now under contract, amounting to about $1,500,000, are laid out on what the department calls the duplex system. This method of overcoming the difficulty was first suggested by Mr. Blatt, assistant engineer of the High-Pressure Bureau. It consists of laying two entirely independent systems of mains and hydrants in alternate streets, the hydrants of one system being painted red and the other green. The mains are so laid out that at nearly all intersections of streets hydrants of both colors are available.

9 Should a break occur in either system, the operator at the pumping station would at once know in which system the trouble was located by looking at the venturi meters, and by throwing a switch he would start the closing of two electrically driven valves, separating one system from the other. Hydrants would then be available and in service pending the location and isolation of the damaged section.

10 The section now in operation was designed to give 20,000 gal. per min. on any one block with a loss due to friction from pumps to hydrant not to exceed 40 lb. The duplex extension will give the same results, and should either half be out of service by an accident, there will still be available at the same location 10,000 gal. per min., with a loss from the pumps to the hydrant in the most unfavorable location not exceeding 50 lb.

RICHARD H. RICE. This paper shows that the installation described has been made after the most careful study and a very intelligent choice of the types of apparatus to be used. The choice of the centrifugal pump for the work described is thoroughly justified by its simplicity and by the efficiencies obtained. The choice of alternating current as the source of power, in view of the unlimited supply of current existing and the duplicate means of conducting it into the station, is also justified. The centrifugal pump is today the popular means of producing pressure for emergency fire purposes, as in the fire boats of New York, Chicago, Duluth and San Francisco, and the new high-pressure service of San Francisco. In San Francisco twelve of these pumps are now being installed, four on fire boats and eight for an auxiliary fire installation. On the fire boats centrifugal pumps are particularly adaptable as they can be run in series or in parallel. In parallel they give 150 lb. pressure, and in series the pressure is doubled. This pressure is particularly valuable where walls have to be battered down, or streams thrown long distances.

2 In cases where electricity is not so available as it is in New York, steam turbines are being installed, and they offer advantages over the gas engine, where maximum reliability is considered.

3 As an emergency installation pure and simple, I think the installation mentioned in the paper can be still further simplified. I believe the speeds chosen for operating the pumps are too low, and that the pumps contain too many stages. I have had occasion to make extensive researches in centrifugal pump design with special reference to operation at steam-turbine speeds, and have found that

they can be operated at high speeds with a smaller number of stages, giving efficiencies comparable with those obtained here, although the question of efficiency is subsidiary to reliability for this service. Pumps for this service should be designed with two or three stages at the most, and with considerably higher speed.

4 Pumps can also be designed without balancing pistons, which are undesirable from the viewpoint of possible interruption of service. An inspection of Fig. 5, illustrating the construction of the pumps, will show that the balancing pistons used are quite liable to damage if water containing sand or other impurities is used, and this damage would very probably result in stoppage of the pump when it is badly needed. The use of balancing pistons is unnecessary in such emergency apparatus and should be avoided.

C. A. Hague. A question has been asked several times with reference to the results of tests of efficiency on centrifugal pumps operating singly and in multiple or group. Professor Carpenter has given the very plausible explanation that the difference in efficiency in favor of the pumps running singly is probably due to the presence of eddies and disturbances in the pipes when the pumps are operating together and the absence of such eddies and disturbances when only one pump is at work. In my experience in installing pumps and condensers singly and in groups I have found them extremely sensitive to each other in operation, both in taking in and discharging the water, when more than one pump is working on a line.

2 In the Manhattan stations, it seems to me that the suction or inlet pipes and the discharge pipes are coupled too closely for best efficiency; and also that the inlet pipe close to the pumps is not large enough for operation in multiple, although perhaps ample for a single pump when the water is undisturbed by the draft and discharge of several pumps. I have experimented considerably in that line, and have found that a comparatively large body of water next to the pumps on the suction side will materially ease the machines in their performance. The idea is to come up to the building with a normal supply pipe, and then enlarge it very considerably just where it enters the building, providing the inlet pipe with a good-sized air chamber wherever possible. I have tried this several times with excellent results.

3 Mr. Brown mentioned the difficulty of cutting in with a second pump where the first pump was already running, a difficulty which

I think is also due to too close connections along the inlet and outlet lines and a cramped condition generally. Of course, a disturbance in the water column and in the hydraulic horsepower would unbalance the electric power to a certain extent, perhaps not much, but the total disturbance may very easily result in the loss of several points in the efficiency.

4 Considering the fact that the city pays by the kilowatt-hour for its electric current as per switchboard reading, it would be no more than proper to state the efficiency of the machine as a whole, and not exclusively upon the basis of motor efficiency obtained in the shop of the makers a thousand miles or so away. In this case when 100 h.p. in current is supplied to the switchboard, the motor has shown an output by a competent test of 93.2 h.p.—Par. 37—the 6.8 h.p., although charged against the city in the power bills, being lost in heat and friction. Then, all that is charged against the pump is 93.2 h.p. The 67.57 h.p. shown by the pump for each 100 h.p. at the switchboard indicates only 67.57 per cent total efficiency, although the 67.57 h.p. indicates 72.5 per cent efficiency of the power delivered by the motor. I have tested several centrifugal pumping plants of various sizes and powers, and the total efficiency generally shows from 64.5 per cent to about 68 per cent and very seldom above the latter figure.

5 Mr. Bibbins touched upon the possibilities of utilizing the centrifugal pump for waterworks service, but upon investigation he would find a vast difference between emergency service, where operating economy counts for little in the face of great danger from fire, and the steady and necessarily economical service required for the continual pumping in waterworks stations. To show how deceptive a portion of the truth may be, a case is cited where a pumpage of a capacity of 10,000,000 gal. per day against 110 lb. load could easily be accomplished with displacement steam machinery by an expenditure of $10,000 per annum for coal. But an attempt to drive centrifugal pumps by electricity resulted in a cost for electrical power, at $6.50 per 1,000,000 gal., of $23,725 per annum; showing a difference in favor of displacement steam machinery that would pay 5 per cent per annum on $275,940. There is no conceivable difference in cost of machinery, buildings, maintenance, attendance, or anything else, that would justify such a preference for electricity and centrifugal pumps over steam and displacement pumps. Note the following figures:

10,000,000 gal. daily, against 110 lb.	440 pump-h.p.
120,000,000 steam duty with 8 lb. evaporation in the boilers, coal at $2.50 per net ton delivered	$9928 per annum
Electric power at $6.50 per 1,000,000 gal. against 110 lb. means 3,650,000,000 gal. per annum at $6.50	$23,725 per annum
The difference in cost for the element of power is $13,797 per annum, which at 5 per cent would capitalize at	$275,940

6 The steam-driven, reciprocating, displacement pumping engine can show a mechanical efficiency, from the power put in through the throttle, to the water-horsepower of the pumps, as high as 96 per cent, never as low as 90 per cent, under the above conditions. The centrifugal pump when steam-driven has a corresponding efficiency of about 65 per cent, and when electrically driven of about 67 per cent. A comparison of tests is given in the tables, in which it will be seen that the steam plant saves enough to pay 8.6 per cent on its entire cost.

TABLE 1 COST OF OWNING AND PUMPING WITH HIGHEST TYPE AND CLASS OF STEAM PUMPING MACHINERY

ONE UNIT, STEAM-DRIVEN, RECIPROCATING, DISPLACEMENT MACHINERY, CAPACITY OF 25,000,000 GAL. AGAINST 87 LB.

Pump horsepower	870
Boiler horsepower for triple-expansion vertical pumping engine	450
Engine house and foundations and engine foundations	$150,000
Boiler house and foundation, boiler foundations, chimney, etc	
Vertical triple-expansion pumping engine	
450 h.p. of boilers	
Building for coal supply	

CHARGES AGAINST PLANT—PUMPING ENGINE

Interest	4 per cent
Sinking fund	5 per cent
Depreciation	2 per cent
Oil waste, etc	1 per cent
Total	12 per cent

CHARGES AGAINST PLANT—BOILERS

Interest	4 per cent
Sinking fund	5 per cent
Depreciation	5 per cent
Total	14 per cent

3 engineers. 6 firemen. 3 oilers.
Coal at $2.10 per net ton

SUMMARY FOR STEAM RECIPROCATING MACHINERY

Coal per annum	$11,957.40
Wages per annum	9,900.00
Capital charges on engine	13,920.00
Capital charges on boilers	1,260.00
Capital charges on buildings	1,548.00
Total charges per annum	$38,585.40
Cost per 1,000,000 gal	$4.11
Cost per horsepower	43 16

TABLE 2 COST OF OWNING AND PUMPING WITH HIGHEST TYPE ELECTRO-TURBINE PUMPING MACHINERY

ONE UNIT, ELECTRIC-DRIVEN, CENTRIFUGAL MACHINERY, CAPACITY 25,000,000 GAL. AGAINST 87 LB.

Pump horsepower	870
Two-stage, electric-driven centrifugal pump	$43,750
Engine house and foundations and pump foundations	
Transformer house and foundations	
Transformers, lightning arresters, conductors, controllers and auxiliaries	

CHARGES AGAINST PLANT—PUMPING MACHINERY, ETC.

Interest	4 per cent
Sinking fund	5 per cent
Oil, waste, etc	1 per cent
Depreciation	2 per cent
Total	12 per cent

3 Engineers. 3 Extra men
Electric current, $4.50 per 1,000,000 gal.

SUMMARY FOR ELECTRIC-TURBINE MACHINERY

Electric current per annum	$41,062.50
Wages per annum	5,700.00
Capital charges on machinery	4,314.00
Capital charges on buildings	468.00
Total charges per annum	$51,544.50
Cost per 1,000,000 gal	$5.64
Cost per horse power	59.21

THOS. J. GANNON. In reply to Mr. Hague I will read the conditions which occurred on the evening of January 7, when both pumping stations were put to a crucial test:

7.22 First alarm, Hudson and Franklin Sts.
7.28 Second alarm, Hudson and Franklin Sts.
7.29 Third alarm, Hudson and Franklin Sts.
7.46 Fourth alarm, Hudson and Franklin Sts.
7.54 First alarm, Bowery and Hester Sts.
8.17 Automatic, Mercer and Houston Sts.
8.19 Second alarm, Bowery and Hester Sts.
8.29 First alarm, Mercer and Houston Sts.
8.32 Third alarm, Bowery and Hester Sts.
8.40 Second alarm, Mercer and Houston Sts.
8.43 Third alarm, Mercer and Houston Sts.
8.45 Fifth alarm, Mercer and Houston Sts.

2 In due time seven pumps were put into operation, with a discharge which reached at times over 35,000 gal. per min., and it was estimated that over 52 fire streams were in service at the same time. Each pump responded instantly and remained in service until ordered shut down. The pressure was ordered gradually increased from 125 lb. to 230 lb., where it was maintained throughout the greater part of the time that the fires raged. The operating force at each pumping station consisted of but one engineman, one oiler, one telephone operator and one laborer.

PROF. GEORGE F. SEVER. A question was asked as to the feasibility of using the storage battery capacity to invert the rotaries and provide alternating current, to be spread through the alternating-current system to the sub-stations, and from those to provide alternating current to the pumping stations. In our preliminary investigation, if I recall the facts correctly, we were assured that this could be done; giving us another feature of reliability in the operation of the system. If the Waterside station should go out of business, we could still get current from the sub-station.

A. C. PAULSMEIER.[1] While the reasons given in the paper for the selection of electric-driven turbine pumps do not coincide with the conclusions as to reliability that have been reached in the West, there can be no question about the careful study given by the engineers who planned the high-pressure fire system described.

[1] Chief Engineer, Byron Jackson Iron Works, San Franciso, Cal.

2 The pumps show a remarkable efficiency, and one of the principal points that should commend them to those interested is their great flexibility as to capacity, a characteristic that every fire pump should possess.

3 The eight fire pumps now being built for the City of San Francisco are of a combined capacity of 216,000 gal. per min., under a working pressure of 300 lb. Each of these pumps is driven by a 750-h.p. Curtis steam turbine, operating at a normal speed of 1800 r.p.m.

4 In addition there are now being completed four fire pumps for the boats Dennis Sullivan and David Scannel, of an aggregate capacity of 9000 gal. per min. under 300 lb. working pressure, or 18,000 gal. per min. under 150 lb. working pressure, the pumps being so arranged that they work either in series or in parallel. The pumps have all been subjected to 24-hr. tests, and while the data on these tests are not sufficiently complete for publication, it was shown that the pumps are not as flexible as to capacity, or are not as capable of pumping an excess quantity of water, as are the Manhattan pumps. The reason for this is that the impellers in the San Francisco pumps are only 13⅝ in. in diameter, while the inlet to the impellers is less than 10 in. in diameter, this opening being further restricted by the pump shaft, so that it is impossible to obtain much excess water from these pumps, no matter how much below the normal the discharge pressure is carried.

5 In the station pumps now being built the velocities at the entrance to the impellers have been somewhat decreased, although it is impossible to make anything like the excess capacity shown by the Manhattan pumps, which have impellers of such a size that the inlets may be made anything consistent with good practice.

W. B. Gregory. It is gratifying to know that efficiencies ranging from 70 to 80 per cent may be obtained with well designed five-stage turbine pumps. The high-pressure fire-service pumps in New York represent one extreme of conditions, while at the other extreme is the centrifugal pump used in the rice irrigation territory of Louisiana and Texas for raising large quantities of water through comparatively small lifts.

2 The improvement in design of pumps of the latter class in the last ten years, and especially in the last five years, has made it possible to specify an efficiency of 75 per cent, even with heads as low as 10 ft. Purchasers of pumping plants in this section are no

longer satisfied with pumping outfits having efficiencies ranging from 50 to 60 per cent.

3 As examples of the results obtained with pumps of the class that deals with large volumes of water, the tables are quoted from recent acceptance tests conducted by the writer, of pumping plants used for rice irrigation.

TABLE 1 ACCEPTANCE TESTS

TANDEM-COMPOUND CONDENSING ENGINES, DIRECT-CONNECTED

Cane and Rice Belt Irrigating Company, Fulshear, Texas, August 12 and 14, 1908

WORTHINGTON PUMPS	FIRST LIFT	SECOND LIFT
Size of pump (diameter discharge pipe), in	45	45
Water pumped, gal. per min	47,620	46,430
Head on pump, ft	33.90	13.95
Efficiency of engine and pump, %	69.5	73.6
Efficiency of pump (engine 93 %)	74.7	79.2

CROSS-COMPOUND CONDENSING CORLISS ENGINE, DIRECT-CONNECTED

Sabine Canal Company, Vinton, La., May 22, 1909

WORTHINGTON PUMP	
Size of pump (diameter discharge pipe), in	45
Water pumped, gal. per min	44,010
Head on pump, ft	23.26
Efficiency of engine and pump, %	69.5
Efficiency of pump (engine 90 %)	77.3

TANDEM-COMPOUND CONDENSING CORLISS ENGINE, DIRECT-CONNECTED

Second Lift, Neches Canal, July 16, 1909

MORRIS MACHINE WORKS PUMP	
Size of pump (diameter of discharge pipe), in	48
Water pumped, gal. per min	60,300
Head on pump, ft	10 12
Efficiency of engine and pump (maximum), %	69.9
Efficiency of pump (engine efficiency 93.2 % max.)	75

CHARLES B. REARICK. Electrically driven fire pumping-stations for large cities are dependent upon current from an outside source, usually a large central power plant. It would seem quite practicable in many cases to locate new fire pumping stations adjacent to some large power plant having considerable boiler capacity. In such cases it would be possible to drive the centrifugal or turbine pumps with steam turbines, and thus eliminate the necessity of large over-

load capacity in electric generating units for the central station, and also the liability of derangement of the lines between the power stations and the pumping stations. The charge for standby service per annum should be less than for similar electric service.

2 The steam turbines have the advantage of being operative at any speed, and in this manner will maintain in the discharge mains any pressure desired. Furthermore, automatic regulating valves can be used in connection with the turbine to maintain constant pressure irrespective of demand or flow.

3 It is probable that the cost of installation would be less than for electric-driven units. The turbine could run non-condensing, as the question of steam consumption is of small moment for fire service.

HENRY E. LONGWELL. The last paragraph of the paper furnishes a striking illustration of how purely academic is the ordinary official efficiency test, and how valueless it is as a basis on which to predicate the results that may be expected when the plant is operated under normal service conditions.

2 The average net pressure against which the 14,095,000 gal. was pumped with a current consumption of 81,450 kw-hr. is not stated. Assuming that it was 300 lb. net per sq. in., the pump efficiency, after allowing for the losses in the motor, would be only 40 per cent. However we know that for part of the time the pressure did not exceed 225 lb., or, considering the pressure in the suction mains, about 200 lb. net. If the entire quantity of water had been pumped against this lower pressure, the efficiency would be well under 30 per cent. It is therefore perhaps fair to assume that the actual average efficiency was not far from 35 or 36 per cent, or say, in round numbers, only one-half that reported as shown on the official test.

W. M. FLEMING. With the rapidly increasing size and height of office buildings, the annual fire loss in the business districts of the cities of the United States is increasing to an alarming extent. The installation of these tremendously effective fire-fighting systems has already proved of definite value in the reduction of city fire losses, and consequently of insurance costs.

2 What was probably the pioneer large and independent so-called high-pressure fire system in this country was installed at Philadelphia in 1903-1904. This plant differs in almost every important detail from the New York system more recently installed;

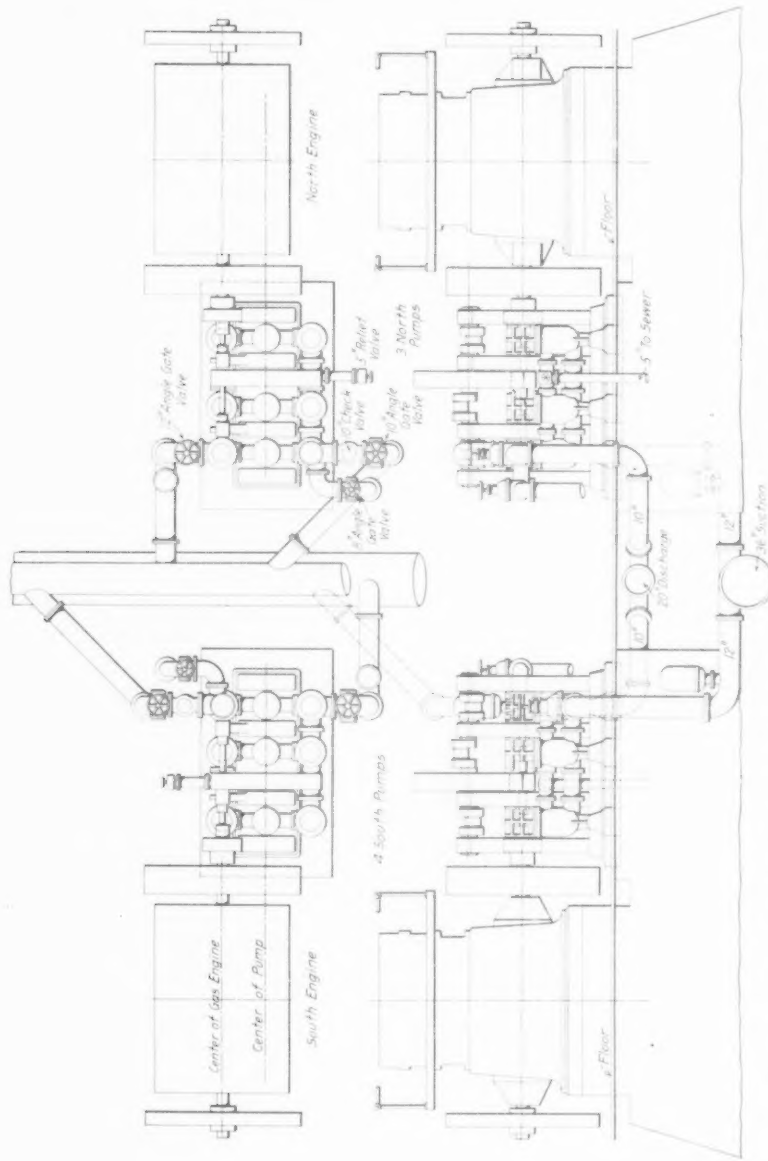

FIG. 1 GENERAL ARRANGEMENT OF THE PHILADELPHIA HIGH-PRESSURE FIRE-PUMPING SIATION

yet the general results in both cases have been excellent. In Philadelphia the plant has so many times proved of great value in actual service that a much larger fire-fighting system, consisting of pumping units identical with those originally selected, is now being installed to protect what is known as the Kensington mill district.

3 From the original Philadelphia station at Delaware Ave. and Race St., a location unlikely to be seriously injured by conflagration, Delaware River water is supplied to independent high-pressure fire-service mains which effectually cover more than 425 acres at the center of the business district. The pumping units consist of vertical double-acting triplex power pumps built by the Deane Steam Pump Company, direct-connected to Westinghouse

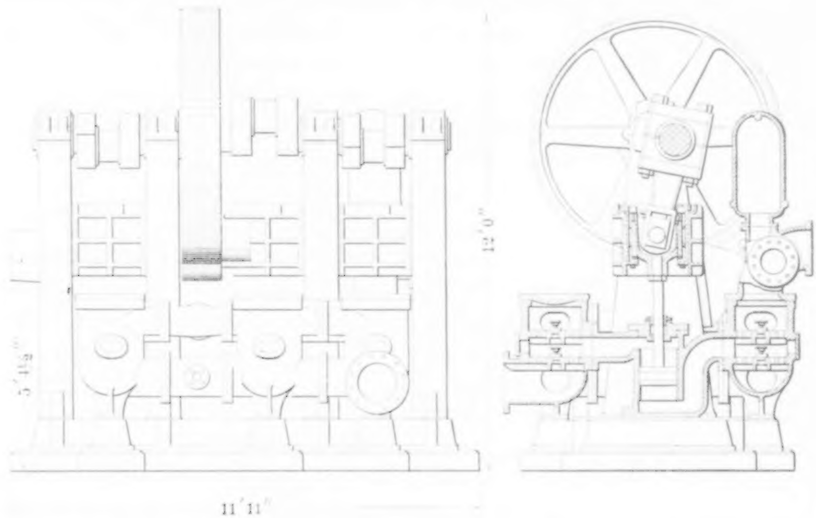

Fig. 2 Side and Sectional End Elevation of Triplex Pumps for the Philadelphia High-Pressure Fire-Pumping Station

vertical 3-cylinder 4-cycle gas engines each of 280 h.p. The seven large pumping units have each a nominal capacity of 1200 U. S. gal. per min., at 300 lb. pressure, and two small units have a capacity of 350 U. S. gal. at the same pressure.

4 The general arrangement of the Philadelphia pumping station is similar to that of the large New York installations. (See Fig. 1.) Two rows of pumping units occupy the main floor of the station. The pumps are nearest the center, and the gas engines are located in the same relative positions thereto as the motors in the New York

pump houses. A platform extending along the sides of the building, about ten feet above the floor, serves as a working gallery for the operation of the engine throttles. Space is provided for the installation of three additional pumping units, and all mains are proportioned with the ultimate probable capacity of the plant in view. Suitable connections are provided to the mains so that the capacity of the pumping station may be supplemented by the use of the city's powerful fire boats, should occasion require.

5 The internal combustion engines are of the well known standard Westinghouse type and require little explanation. Speed regulation with varying loads is accomplished by the action of a centrifugal governor controlling the quantity of combustible admitted to the cylinders. Ignition is by a very neat type of make and break mechanism contained in a cylindrical plug. Two independent igniters are provided in each cylinder, and three independent sources of ignition current are available at all times. The engines are started by the use of compressed air, which is admitted to one of the cylinders at the proper time to secure rotation in the direction required until the regular cycle of operation is established. The pumps are started under no-load.

6 The pumps are of the vertical, double-acting piston, triplex power type, requiring comparatively small floor space and giving a rate of discharge so smooth and uniform as to make imperceptible at the hose nozzles any pulsation in pressure.

7 Fig. 2 is a sectional view of one of the pumps, indicating quite clearly the extreme simplicity and accessibility of the machine, and its general construction. All valves are of the poppet type, readily accessible through handhole openings. Valve areas and waterways naturally are comparatively large, so that friction losses are reduced to a minimum. The water ends are thoroughly brass-fitted in order that the pumps may be readily started after a long period of disuse.

8 There is a connection through a 12-in. check valve, from the city mains to the high-pressure system, so that the mains and pumps are constantly primed with a pressure of 60 lb. and are ready for service at all times. A complete system of fire-alarm boxes and telephones, with underground wires, permits direct communication between the vicinity of any fire and the pumping station. On the sounding of the alarm, the station force, consisting of an engineer and his assistant, can bring the total plant of seven large units into service in seven minutes, and have repeatedly done so. Work-

ing pressure is invariably available at the hydrants one minute from the time of the alarm. Such a result would be impossible with ordinary movable apparatus.

9 The pumping units are started up under no-load, by the use of a motor-driven by-pass valve, through which the pump discharges into an overflow, until the normal cycle of operations has been set up in the gas engine, when the switch is closed, causing the by-pass valve to close and the discharge to be directed into the fire mains.

10 Experience has indicated that the maximum pressure of 300 lb. is required only for the most extensive fires, and for fires in the higher parts of tall buildings. The pressure records show that probably 75 per cent of the water pumped is required at not more than 150 lb. to 175 lb. pressure. The pressure desired in each case, is dictated over the telephone by the fire chief, the required pressure regulation being obtained by proportioning the number of units in operation to the requirements.

11 The practical results of the use of the Philadelphia fire system have been: material reduction in fire losses in the protected district, large decrease in fire insurance rates, and a greater willingness on the part of property owners in the protected section to erect pretentious office buildings.

12 Though the writer is unable to present a statement as to the annual saving to property owners by the installation, yet in view of the low cost of operation of the plant, there can be no question but that it presents a considerable yearly saving to the city. During the year 1907, which is perhaps typical, water was delivered to 16 fires, the longest one lasting 44 hr. The plant responded to 116 alarms at which no service was required. The operating expenses for the year were as follows:

Gas, 839,488 cu. ft. at $1.00	$839.49
Electric lighting	343.99
Electric power	7.98
65 tons pea coal at $3.50	277.50
Supplies furnished the pumping station for the entire year 1907	1,500.00
Total fixed charges for 1907	$2,968.96

SUMMARY

Salaries (Total for entire staff)	$8,389.72
Total cost materials	2,968.96
Total operating expenses	$11,358.68
Total daily maintenance charge, salaries and operation	$31.12

13 No mechanical defects have yet developed in either engines or pumps, and practically the only replacements have been a few rubber valves for the pumps and ignition details for the engines.

14 While no definite comparison can be made between the small plant in Philadelphia and the comparatively large plants in New York, which have not yet been in operation for an appreciable length of time, the operating expenses of the Philadelphia plant seem likely to prove much less for a given quantity of service. This is largely due to the so-called "readiness-to-serve" charge made by the company furnishing power to the New York plants. To this charge must, of course, be added the actual cost of the current consumed.

15 Unfortunately no mechanical efficiency test has ever been made on any of the Philadelphia pumping units. Judging from tests of similar machinery, an efficiency of 80 to 85 per cent is to be expected from pumps of this character operating against 150 to 200 lb. pressure. If this is the case, knowing that 75 to 80 per cent of the water to be used will be required at pressures not to exceed 175 lb., it would seem that the plant efficiency in Philadelphia would prove greater than in New York, where we understand that the water must be delivered through reducing valves from 300 lb. to any lower pressure required.

Note: The discussion of this paper at St. Louis will be published later, with the author's closure.

STRESSES IN REINFORCED CONCRETE BEAMS

By Prof. Gaetano Lanza and Lawrence F. Smith,[1] Published in The Journal for Mid-October

ABSTRACT OF PAPER

This paper presents a comparison, in the case of eleven beams, of (*a*) the position of the neutral axis, (*b*) the stress in the steel, (*c*) the greatest compressive stress in the concrete, (*d*) the greatest deflection of the beam as determined by experiment, with the same quantities as computed by each of three well-known theories of the distribution of the stresses, these theories being designated by *A*, *B* and *C* respectively. *A* and *B* both neglect the tension in the concrete, but differ in the mode of distribution of the compression; while *C* takes account of tension in the concrete. The results show a better agreement with the results of the experiments when tension in the concrete is considered than when it is not. This is especially so in the case of the stress in the steel and in the position of the neutral axis, and, to a lesser degree, in the greatest fibre stress in the concrete and in the deflection.

DISCUSSION AT BOSTON

Chas. T. Main. All engineers, civil, mechanical or any other, want to know the most accurate way of figuring the stresses in reinforced concrete. What I am more anxious to know is that the proper ingredients are used, with proper mixing and good workmanship, so that we may be reasonably sure of a factor of safety in the finished work somewhere near what was intended. I have done no work of this sort without constant supervision, and am obliged to say that I have done no work that has been a source of pleasure to me. All of the building materials in common use are, I think, more certain in results than reinforced concrete. It is quite necessary to improve in the use of this material and in workmanship, in order to produce work which will inspire confidence.

[1] Instructor, Mass. Inst. of Tech.

Sanford E. Thompson. Professor Lanza's paper is of much value as a means of comparing the various formulæ used in designing reinforced-concrete beams, with the behavior of test beams under load. Of the three theories the straight-line theory A is the simplest, and to the writer this still seems the best from a practical standpoint.

2 The formula derived by this theory as now used for determining the depth of a reinforced concrete rectangular beam (using the notation adopted by the Joint Committee on Concrete and Reinforced Concrete[1]) may be expressed simply as

$$d = C\sqrt{\frac{M}{b}}$$

and the ratio of steel required is $A_s = pbd$

where d = depth of beam from compressed surface to center of steel, in inches.

C = a constant for a given steel and a given concrete.

M = moment of resistance or bending moment in general, in inch pounds.

b = breadth of beam, in inches.

A_s = area of cross-section of steel, in square inches.

p = ratio of cross-section of steel to cross-section of beam above the center of gravity of the steel.

3 Theory B, where the stress is taken as varying according to a parabola, is perhaps more exact than theory A, but at the same time more complicated and difficult in practical application. Theory C agrees more closely in the earlier stages of loading with the tests, although tests made both in the United States and in Europe indicate that Considère was not entirely correct in his assumption that steel when combined with concrete permits the concrete to stretch to a greater degree than when not reinforced. However, at earlier stages of loading the cracks in the concrete do not extend up to the neutral axis, so that more or less of the concrete is resisting tension and assists the steel in taking the stress. For this reason a method taking into account the tensile value of concrete gives results closer to the tests at early periods of loading than either formula A or B.

[1]The Joint Committee is composed of representatives from the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway and Maintenance-of-Way Association, and the Association of American Portland Cement Manufacturers.

There are, however, quite important reasons, as will be shown in succeeding paragraphs, why theory A is preferable.

4 Reinforced concrete is a complex material, which if properly used gives very safe and satisfactory structures. It is not, however, of a kind to which hair-splitting accuracy may be applied. In selecting a formula to use, the aim should be to choose one which will give results always on the safe side and at the same time not very wide of the mark. Referring to the paper, formula A gives results on the safe side, while C errs nearly as often on one side as on the other.

5 The behavior of a reinforced-concrete beam under load may be divided into two stages, the earlier stage where the concrete under the neutral axis bears tension, which gradually merges into the later stage, when the tensile strength of concrete is overcome and all the tensile stress is taken up by the steel. In the earlier stage the stress in steel increases proportionally to the moment, while in the later stage the increase in stress in steel is composed not only of the increase proportional to the moment, but also of the stress which in the previous stage was carried by the concrete and after its cracking transferred to the steel. Thus, for example, if a certain load W stresses the steel up to, say 16,000 lb. per sq. in., an addition to the load of *less* than W will double the stress. Therefore, a beam designed for a load which would produce an actual stress in steel of 16,000 lb. per sq. in. would have a factor of safety smaller than the ratio of that stress to the elastic limit of the steel. It is safer, then, to base the design on the results at the breaking load rather than on the results at earlier stages of loading, and to use theory A, which at the breaking load corresponds closely to the tests, and so be sure of the required factor of safety. In designing, working stresses and working moments should be used in the formulae.

6 The strongest argument against computing the concrete to bear tension, in practical design, is the fact that reinforced-concrete floors and other structures usually have to be built with joints between two days' work. The bond of the concrete on the joints is imperfect, and consequently the tensile strength of concrete at that point is small and cannot safely be counted upon in design.

7 Theory A is very simple and clear. It has been adopted quite generally in Germany and England, and I believe also in France, although that is the home of Considère, while the Joint Committee in this country has recently adopted it.

8 Theory A when used in figuring deflection does not give very satisfactory results, but this is not an important factor in reinforced-

concrete design. When necessary to compute deflection, a more complicated formula may be used which considers the tensile strength of concrete. The best of such formulæ known to the writer are those derived by Professor Thullie of Austria, which are based on more logical assumptions than are the formulæ of Considère.

9 It must not be forgotten that the computation of the stress in the middle of a supported beam is only one part of the theory of reinforced-concrete design. Just as important as the design of the beam in the center, since reinforced concrete is usually built continuous over several supports, is the design of the ends of the beam, and of no less importance is the part of the design to resist the tendency of the diagonal tension to produce diagonal cracks.

10 It may be said then in conclusion, that although not corresponding strictly with tests, the ordinary straight-line theory is the one which will probably be used for some time to come because of its simplicity, and because reinforced-concrete beams, designed according to this theory, with due regard to other details, will produce with good workmanship, structures which are unquestionably safe and conservative.

11 Except for a few isolated examples, it is less than ten years since reinforced-concrete buildings began to be erected; the 16-story Ingalls building in Cincinnati was built in 1903, and still stands as the most notable example of a concrete office building. And yet, as has been stated by Professor Burr, we already know more about concrete columns than about steel columns; the tests have been more exact, and more nearly conform to practical conditions. The beam theory is still in the stage of development, and tests and mathematical demonstration which tend toward more economical and rational detailing are welcome. Nevertheless, we may say with surety that buildings all over the country which are being designed by the common formulae with conservative stresses, and erected with proper care, are safe and conservative.

F. S. Hinds.[1] I have had a very profitable experience in the last two or three years in the construction of a large office building built entirely of reinforced concrete, erected for the Phelps Publishing Company at Springfield, Mass. The building covers an area of 30,000 sq. ft. and is eight stories above the sidewalk. In the construction of the building it was demonstrated that good work can

[1]F. Sumner Hinds, Boston, Mass.

be done with reinforced concrete, and that there was no mistake in selecting concrete for both the interior and the exterior of the building.

2 My observations have led me to believe that we will see this construction in buildings even higher than eight stories. In fact, there is such an office building in Cincinnati, 16 stories above the sidewalk, showing that reinforced concrete can be used in competition with the steel frame.

3 Answering a number of questions by Desmond FitzGerald, Mr. Hinds said that the concrete for the building was mixed by machine, crushed stone of "pea" size being used. The proportions of the mixture were 1-2-4, just enough water being added to make the mixture solid and yet make it flow easily. The ramming of columns was not done in the usual way, but the concrete was settled by means of four or five poles. Both round and twisted rods were used, held in place by small wood blocks which were withdrawn as the mixture was poured into the form.

4 Continuing, Mr. Hinds said that the great secret in concrete work is in getting the rods in the proper places. Supervision and careful preparation of the mixture and handling of materials will bring the best results. An oil paint and cold water paint without plastering have been used on the inside of the building, showing how smooth the surface was finished.

5 In answer to a question Mr. Hinds said that moisture was prevented from going through the walls by their thickness—none being less than 8 in. thick—and by the density of the concrete. He had seen no cracks whatever in the reinforced concrete proper, the only crack in the building being one near the top of the elevator-well partition, caused by expansion and contraction. Here and there a small crack appeared in the granolithic floor.

PROF. C. M. SPOFFORD.[1] I presume we all agree with the previous speakers that concrete should be handled carefully, as it is subject to great variations. I feel, however, that merely to be careful is not enough; we should determine the theories as correctly as possible, and use them to eliminate so far as possible such uncertainties as now exist.

2 I am surprised that the C formula, as Professor Lanza has called it, gives results closer to the results of actual experiments than

[1] Massachusetts Institute of Technology.

the other formulæ, and hope that the present data may be extended by further tests and computations. As far as actual use in design is concerned, any one of these theories may be safely used, provided a liberal factor of safety is employed, but further study and investigation along the lines indicated may enable us to determine more precisely what the factor of safety should be.

Henry F. Bryant.[1] I would like Professor Lanza to tell in what way the tested beams failed; whether there were distinct signs of failure at the yield point of the steel, and whether that is the definite point of failure in the beams which he tested. I would also like to ask whether as a result of the tests, he has any evidence that exceeding the yield point of the steel, if it is reached without diagonal crack, is the cause of the failure of the beam.

J. R. Worcester.[2] The careful study which the authors have devoted to these eleven beams is of great value, and their deductions show how much can be learned from a few experiments made with care and recorded with scientific accuracy.

2 It seems to the writer, however, that a few other points of interest in the tables are worthy of comment; as, for instance, the fact that in two of the beams, A-1 and A-2, alike so far as dimensions and amount of reinforcement are concerned, there appears to be a variation of 0.1 in. (1.9 per cent) in the actual location of the neutral axis; of 76 lb. per sq. in. (12 per cent) in the stress in the concrete; of 297 lb. per sq. in. (3.9 per cent) in the stress in the steel, and of 0.007 in. (10 per cent) in the deflection.

3 Another remarkable variation in the behavior of beams apparently alike is that of No. 35 and No. 45, where the latter with 80 per cent of the load of the former had the same actual deformations in steel and concrete, indicating the same location of neutral axis, and at the same time 50 per cent greater deflection. These great differences may perhaps be due to the fact that No. 45 was cracked before the test began, and therefore possibly should be excluded from such a comparison as this, though the cracking did not prevent the beam from developing fairly satisfactory strength. These striking instances of variation in observed results, where every precaution was taken to make the conditions identical, render it important to select theories of computation safe for the worst results found experimentally.

[1]Henry F. Bryant, Boston and Brookline, Mass.
[2]J. R. Worcester, 79 Milk St., Boston, Mass.

4 Speaking from a practical standpoint, several of the elements compared are not of vital importance. The location of the neutral axis is used only as an intermediate step in the process of calculation, and, if fairly correct results can still be obtained, error in this part of the calculation is not serious.

5 Then, again, the deflection is rarely of great importance. It is comforting to know that beams do not deflect as much as if the concrete had no tensile strength, but practically this is as far as we are usually concerned.

6 The actual compressive stress in the concrete may also be eliminated from consideration in actual construction, if only we can limit the area of steel to such a percentage that we are sure failure from the compression of the concrete will not occur until the steel has been stretched beyond the elastic limit. In this connection it is worthy of note that the beams quoted were with one exception more heavily reinforced than is usual at the present time. With 0.8 per cent of steel, or even with 1 per cent, it is safe to base our calculations for moment upon the stress in the steel only.

7 The element then about which the most interest centers is the stress in the steel, and it is important that we should adopt a method of computation which gives this with the least error practicable, and with that on the safe side.

8 Looking at Table 5 with these considerations in mind, we find little difference between methods *A* and *B*, both giving results well on the safe side. Method *C*, while averaging very closely to actual results; gives errors on the wrong side in five out of the eleven cases cited, in one case, and that the one most resembling usual practice, having an error of nearly 15 per cent on the unsafe side.

9 It is noticeable also that the loads assumed are considerably less than what would usually be considered working loads for the beams in question. Following almost universal practice at the present time, the stress in the steel as computed would be allowed to go to 16,000 lb. per sq. in. This would permit loads on the University of Illinois beams as follows:

No. 11, 5,000 lb. in place of 4000 lb.
No. 27, 12,000 lb. in place of 9000 lb.
No. 28, 10,000 lb. in place of 5000 lb.
No. 33, 7,000 lb. in place of 5000 lb.
No. 35, 8,000 lb. in place of 5000 lb.
No. 45, 8,000 lb. in place of 4000 lb.

Only these six are quoted because the essential facts regarding

them are given in the bulletins of the University of Illinois, while we have not at hand the details of the tests at the Massachusetts Institute of Technology.

10 The diagrams of these beams indicate under the above loads the stresses in the steel indicated herewith, using the authors'

STEEL STRESS UNDER HEAVIER LOADING

Beam No.	Load Used	Stress in Steel, Lb. Per Sq. In.			Error of Calculation Per Cent	
		Actual	By A	By C	By A	By C
11	5,000	15,600	17,700	13,600	+13.5	−12.9
27	12,000	13,500	14,900	12,600	+10.4	− 6.7
28	10,000	14,700	16,600	15,000	+12.9	+ 2.0
33	7,000	12,600	15,200	12,900	+20.6	+ 2.4
35	8,000	13,800	15,750	13,900	+14.1	+ 0.7
45	8,000	15,000	15,750	13,900	+ 5.0	− 7.3
				Average error	+12.75	− 3.6

modulus of elasticity, 30,000,000 lb. In the same table are given the stresses in the steel as calculated by methods *A* and *C*, and the percentage of error by each method.

11 Comparing these results with those obtained by the authors as shown in Table 5, we find that the common method of computation *A* gives considerably closer results to those observed than under the lower loading. The error ranges from 5 to 20.6 per cent, with an average of 12¾ per cent, always on the safe side. On the other hand, by the Considère method, *C* varies from + 2.4 per cent to − 12.9 per cent, with an average of 3.6 per cent on the unsafe side. This would indicate that there is no advantage in adopting the more laborious method, involving the solution of an equation of the fourth degree, at least so far as proportioning the steel is concerned.

12 The chief difference between the two methods, as explained in the paper, is in the assumption in the Considère method of a certain value for tension in the concrete below the neutral axis, and the disregard of this in method *A*. There is no question that under ordinary conditions the concrete has a small amount of tensile strength while the loads are small, but there is grave doubt as to the safety of relying upon a crystalline material under such conditions. Many conditions in actual construction may tend to destroy the tensile strength.

There may be set-joints near the center of the beam; there may be voids near the bottom where the mortar has leaked out; there may be incipient invisible cracks extending to an unknown distance. It is a fortunate circumstance that ease of calculation is on the side of the safer method, for this is a powerful incentive to its adoption.

13 The statement at the opening and close of the paper that "the observations made thus far are not sufficient to furnish means for determining the actual distribution of the stresses," etc., is undoubtedly true, speaking literally and with scientific accuracy. At the same time it should be borne in mind that we are dealing with a crude product which cannot in practice be made with scientific accuracy. It is doubtful whether absolute knowledge of the laws of distribution of stress in a theoretically perfect material would be of any great advantage in designing structures of every-day material. The important question is whether we know enough to design our beams with entire safety and reasonable economy. To this query the writer would unhesitatingly give an affirmative answer. The investigation of these beams tends to confirm this opinion, which is also supported by the constantly accumulating experience with actual construction. We would therefore venture to add two other conclusions to those advanced by the author, namely:

a Experiments indicate that, though precise determination of the laws of stress distribution may be impossible in the present state of our knowledge, sufficiently close approximations may be made for all practical purposes.

b The simple method of calculation, by neglecting tension in the concrete and assuming a straight-line distribution of the compressive stress, is the easiest to apply and gives satisfactory results for the determination of the stress in the steel.

Prof. Geo. F. Swain. I notice that Professor Lanza has used a value of $E = 2{,}335{,}000$ for the beams tested at the Massachusetts Institute of Technology, while for the beams tested at the University of Illinois he has used a value for E of 2,000,000. The beams tested at the Massachusetts Institute of Technology were from 35 to 54 days old, while the beams tested at the University of Illinois were from 60 to 65 days old. The modulus of elasticity ought to increase with age, other things being equal, yet in these tables the reverse is assumed. This fact might account for some of the peculiarities

and the results. Professor Lanza does not state whether he measured the modulus of elasticity.

2 In Table 2, I think the heading of the column "Nearest one-third Load," is a little confusing. Those figures are not very close to one-third the load, and beam *C*-5, which has a larger load than the first three beams, has a smaller value in the third column. I suppose the third column simply means the loads for which computations were made, and that the loads were applied in such increments that the figures given represent the nearest third of the load for which computations were made. Yet it seems rather confusing that for a load of 16,240 lb., the nearest one-third should be given as 4600 lb.

3 With reference to the three theories, I have never believed in Considère's main contention, namely, that by reinforcing concrete such great strains could be produced without fracture; though his explanation is in a certain degree plausible. If a body is stretched so that the molecules are a certain distance apart, nothing can prevent fracture. Ductile material like steel draws down at the point of fracture and is stretched much more there than on the average through the length of the piece. If concrete were a ductile material, its adhesion to the steel bars might prevent any such phenomena as drawing down and thus distribute the strain; but concrete is not a ductile material, and there seems to my mind to be no possibility of the great stretch without fracture which Considère claims.

4 As to the results obtained by the three formulae, I think those given in the tables were precisely what might be expected, because these loads were only large enough to be called working loads; that is, they were nothing like the ultimate load. As a matter of fact there was tension in the concrete, under which condition the steel would be relieved; we would therefore expect that in case *C* the stress in the steel would be very much less than in the other two cases. In practice, also, there is undoubtedly tension in the concrete unless cracks occur. The results of tests made by the Boston Transit Commission show large tensile stresses in concrete beams without reinforcement.

5 However, the question is, what to do in designing. In practice there may be cracks in the concrete, not due to stress, but to the moving of blocks on which the rods are set, making the cement run out, or due to shrinkage or joints or other causes; for which reason it seems to me that in practical designing, engineers are not justified in assuming any tension in the concrete.

6 If Professor Lanza tested the modulus of elasticity of his beams,

I would like to know what was the variation in the moduli of elasticity. Was 2,335,000 the averag ? How did the separate values compare?

HENRY F. BRYANT.[1] Mr. Worcester stated (Par. 9) that on applying his reasoning to the University of Illinois experiments, the nearest one-third load for 16,000 lb. of stress on the steel would be found to be nearly double that given in the paper as approximately one-third the breaking load. This emphasizes the question of the yield point. The rather common practice, as Mr. Worcester states, is to take from 12,000 lb. to 16,000 lb. on mild steel and with this to use about 500 lb. as the concrete compressive strength, which, with concrete of 2000 lb. compressive strength, gives a factor of safety of four or possibly five. If the yield point is the critical point in the steel, we are using a factor of safety of only between two and three in the steel. Mr. Worcester's analysis of the Illinois experiments would indicate that instead of breaking at three times what would be considered a safe working load, the beam would break at not over twice the load. I think that using mild steel and a factor of at least four, and figuring that the yield point is the critical point of the steel, we should apply to the steel something like 7500 lb. or 8000 lb., with 500 lb. compression on the concrete. That means a little larger percentage of steel than is common practice, though it is not unusual to adopt this reasoning with high-carbon steel. I am very glad to see that these experiments point that way.

ROLF R. NEWMAN.[2] Several technical journals have commented on Professor Marburg's tests of Bethlehem steel, in which he obtains some very low values, saying that they considered a well made concrete beam safer than a large Bethlehem beam, because its composition is more definitely known. I would like to ask Professor Lanza whether in his opinion it is correct to say that as much experimenting is needed upon large Bethlehem beams as upon reinforced-concrete beams.

H. E. SAWTELL.[3] Considère's theory of stress distribution agrees very well with the actual tests at about working loads on the eleven beams mentioned in the paper. We know, however, that his theory

[1]Engineer, 334 Washington St., Boston and Brookline, Mass.
[2]Civil Engineer, Boston, Mass.
[3]Structural engineer, with Chas. T. Main, Boston, Mass.

will not agree with breaking-load results as well as either the straight-line or the parabolic theory, which consider that concrete takes no tension stress. We should adopt a theory which will agree quite closely with tests at breaking loads, but which will always be on the safe side for intermediate loads. We can then get a real factor of safety.

2 Referring to Par. 24, it seems likely that when applied to floor beams, a formula will remain only a sort of working hypothesis if our theories are to be based upon test beams which are not more like the beams used in actual practice, and if our compressive value for concrete is based upon plain concrete. The present uncertainty may appear to favor the side of safety, but on the other hand, when too

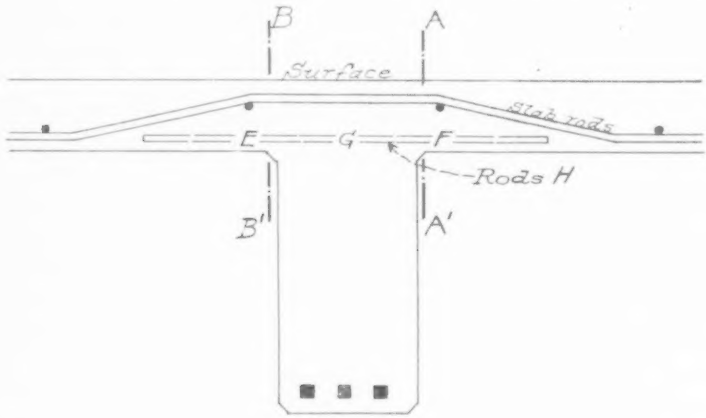

FIG. 1

many assumptions have to be made, there is little real satisfaction in working with the material.

3 Tests on rectangular beams are necessary for determining as nearly as possible the stresses and deflections in slabs and separately moulded beams, but do not seem to solve the problems of beams and girders as used in actual construction. Let us first note some of the stresses as they exist in a beam in actual construction, assuming Fig. 1 to be the cross section of a beam at its place of maximum flexural stress. The slab steel is placed at the beam, as a great many designers consider necessary, in order to resist fully and reliably the negative slab stress, etc., at the beam. These slab rods always are only a few inches apart, and pass through the top of the beam concrete at right angles to the compressive stress of the beam.

4 Assuming that the concrete in both beam and slab is poured at the same time, we know of course that for some distance each way from the beam the slab will work with the beam in resisting compressive stresses. Assumptions are made as to what part of the slabs will work safely with the beam, and then the beam is calculated for and designed as a T-beam. In doing this the full working stress for concrete in compression is used. The concrete at G, E and F has a large share of the compression to take care of. Also, as a result of placing the slab steel at the top, as it passes over the beam, the concrete at G, E and F is again put in compression, this time at its full working value, but at right angles to the compressive stress in the beam.

5 Again, the maximum vertical shear in the slabs is along the lines B-B' and A-A', this shear, it will be noted, being through concrete already doing double duty in compression. The concrete at the surface is at the place of maximum compressive stress of the beam and it also has a maximum tensile stress due to the negative slab moment.

6 The total compression at G, E or F is very much higher than we would willingly put upon plain concrete as a working stress, while the concrete at points E or F is in a worse condition. At the surface the material is nearly cracking from a tensile stress, even under working loads, and it cannot be of much service in compression where it is most needed by the beam.

7 If these conditions are correctly noted, and if the actual stresses are to be kept down to the unit working stress of *plain* concrete, then it will be necessary either to assume a much lower unit stress for concrete when designing T-beams, or to design a rectangular beam whose effective top surface does not extend above the slab rods shown in Fig. 1. But is it necessary to use the value of plain concrete when designing T-beams? Are we not justified in saying that concrete at G is confined, and being reinforced, has a much higher ultimate strength than plain concrete?

8 The compressive strength of concrete in beams is increased in two ways (a) by lateral restraint, brought about by the surrounding compressive forces; (b) by reinforcing its shearing resistance, which may be greatly assisted by placing the rods H at the points shown in Fig. 1. These H rods are to be used only at and near the place of maximum moment in the beam and should be quite close together.

9 But how much does this increase the strength? As bearing upon the subject, an extreme case may be cited from a paper by Leon S. Moisseiff read before the American Society for Testing Materials.

The compressive strength of cubes of concrete, reinforced in every direction by a large percentage of metal in the form of nails, was increased to two to three times the strength of plain concrete. Some designers have already noticed an increase of strength under similar conditions and are taking advantage of it, but are making assumptions regarding its amount for different percentages of reinforcement.

10 So far as the writer knows, no T-beams have been tested with their flanges reinforced and loaded in such a way as to carry their loads to the beam and thus to strain the beam in the same manner as in actual practice. It seems that future tests should be along such a line, if greater economy is to be reached in design and our knowledge is to become more exact with fewer assumptions made.

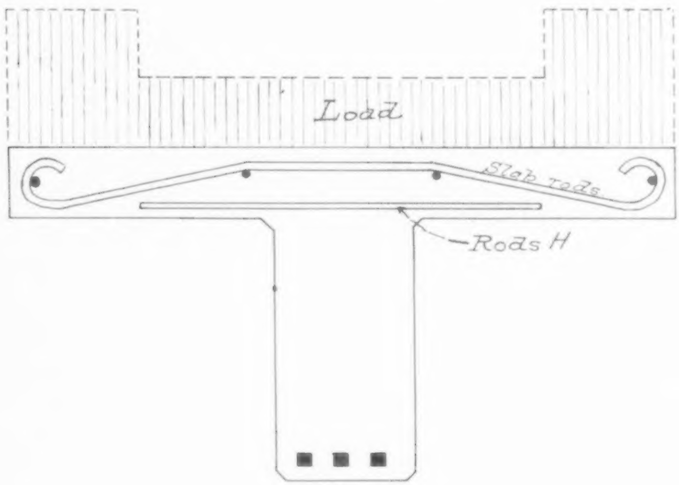

FIG. 2

11 In conclusion, it would seem as though the slab concrete were overstrained at E and F, where it is used for T-flanges, for negative slab compression and for vertical shear from slab loads. Unless it can be ascertained whether lateral restraint, and the use of the rods as shown, will increase the strength necessary to resist this strain safely, it would be better not to calculate for T-beams, but to make the rectangular section sufficient to meet the stress. Even this rectangular section should be designed with a conservative concrete compressive stress, because its top surface is generally considered at about the point where the slab rods pass over it, this including the concrete at G.

12 Fig. 2 shows the cross section at the center of a T-beam, and a method of loading which seems to give promise of results which will come nearer to showing how beams in actual construction are stressed than rectangular beams whose compressive side is wholly plain concrete. The load over the stem should be less than the flange loads; and should agree with actual floor loading where the slabs carry most of the loads to the beam and produce tension in the rods and concrete at the surface over the stem, compression at the under side of the slab at the stem and shear near the stem. As tie rods are always used in practice it would be well to use them here. They are shown by dots in the diagram. The slab rods in this case are bent to act as anchors, and the tie rod at the edge is wired to them on the inside.

13 It is acknowledged that the loads on the flanges do not stress them quite as they would be stressed in a floor system; but if the compression, tensile and shear stresses are not more than those that would be produced, were the slabs continuous, it is thought that as their stress is at right angles to the beam this difference will make no practical difference with the results on the beam.

DISCUSSION AT NEW YORK

E. P. GOODRICH.[1] The several theories which were the basis of the formulæ used by Professor Lanza are approximations to actual conditions, and are made the basis for calculating special points in construction work. The first method is used primarily because of its ease of application to ordinary conditions, and the factors now introduced into the formulæ are based almost exclusively on the results of actual tests. For instance, in the particular series of tests made at the Massachusetts Institute of Technology the ratio of the modulus of elasticity as found by experiment to the computed value is only eight and a fraction. On the other hand, diagrams of Professor Talbot's beam tests, in which the position of the neutral axis is shown, give a ratio of more nearly eighteen, showing that the factor introduced has no real relation to actual conditions. It is the adaptation of a formula to tests, rather than the use of a formula to check various kinds of investigations. Occasionally the straight-line formula has been used to compute deflections and stiffness, as was reported not long ago in an article published in Engineering News; but as to the accuracy of this use there has been some adverse criticism.

[1] Consulting Engineer, 1 Madison Ave., New York.

2 As has been said, Considère's theory was based on certain experiments, the accuracy of which has also been questioned. Professor Mörsch of Zürich argues both for and against them in his book entitled Eisenbetonbau, describing certain experiments with concrete beams, in which he determined the stress-strain diagram for both tension and compression, finding some such conditions as that shown in Fig. 1. If in any beam section, the neutral axis be established, and the actual stresses laid down graphically above and below this neutral axis at any point, and if the centroids in each section are determined, and the distance between them measured, the moment which must theoretically be sustained by the beam can be computed. Mörsch tested

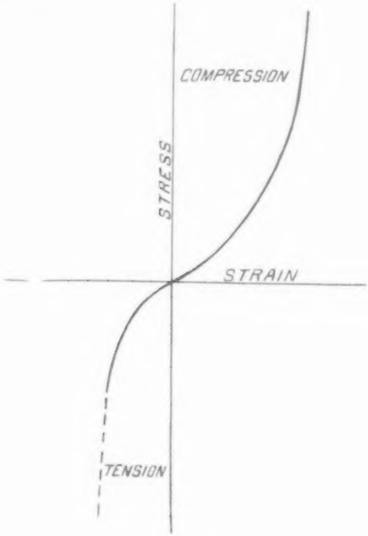

Fig. 1

some specimens both in compression and tension, and also in bending, and computed the theoretical bending moment and ultimate strength by methods similar to Considère's, using a practically constant stress in the concrete below the neutral axis. He found that the theoretical bending stress in kilograms per square centimeter was 20.7, while that found as an average of three actual experiments was 21.4, showing a very close agreement in this particular instance.

3 In the case of three other beams in which the percentage of steel varied from one-half of one per cent to very nearly two per cent, Mörsch made a similar computation based entirely on a stress relation

similar to that of Fig. 1. He found the resultant of the two tensile stresses, in the concrete and the steel, then measured the distance on his diagrams between the centroids of compression and tension, and computed the moment, which was found to correspond closely with the test conditions.

4 Another series of tests of considerable interest is that made by Dr. Mueller for his doctor's thesis for the Hanover Technical High School. He treated concrete beams in a manner similar to that of Professor Lanza, except that he used thirteen points in the depth of the beam, and measured by three methods the actual strain relation which existed at different times. In all his work he used simply a safe working stress, to the limit allowed by the German Government regulations. He found that in a solid beam the stress varied to a certain extent, was very nearly of the straight line type when measured at all his thirteen points; while with a beam in which he built in fourteen artificial cracks by putting sheets of metal close together in the beam, he found that the stress relation more nearly corresponded

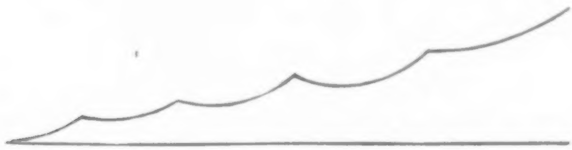

Fig. 2

with Considère's theory These artificial cracks produced a variable stress between the sections, so that the stress in the steel was actually less between the cracks, some of the stress being thrown into the concrete, as illustrated graphically in Fig. 2, in which the ordinates above the base measure the tensile stress.

5 The question of shear has been mentioned, but its effect upon deflections has not been discussed. The writer believes this is very important, because of two series of tests which he made some years ago on beams, one series of which was reinforced only by horizontal rods, and the other by vertical stirrups also. The deflection was three or four times as much in the case of the beams without the vertical steel—shear reinforcement—as in the case of beams with considerable vertical reinforcement. Each series had exactly the same amount of steel in tension. Of course theoretically the vertical stirrups could not affect the tensile stresses in the bottom of the beam. The ordinary theory by which deflection is computed does not include

a factor for shear, which actually does have some effect on the deflection, both theoretically and, as shown by these tests, practically. It must be taken into account, as well as the tension in the concrete, if the actual conditions in the beam, especially with regard to stiffness and deflection, are to be considered.

6 It seems necessary that some relation between deflection and stress should be definitely determined, because deflections can be more easily measured in any beam test than any other phenomena. Almost every novice determines the deflection, although he does not know the relation between it and the stresses involved. It is only through discussions such as this that some true basis can be reached for the computation of the stresses involved in continuous members.

7 There is another point concerning which the writer has made some experiments. By means of plaster of Paris, ordinary sharp carpet tacks were applied to the sides of a beam, with the points sticking outward. The beam was loaded centrally, and the actual deflection curve was simply picked through a piece of paper from time to time as the load was increased. The curves were then enlarged and used as a basis for comparison with the theoretical elastic curve of a beam loaded centrally. There was a very large discrepancy, which was more nearly coördinated when it was assumed that the load was distributed over a length something like one and one-half or two times the height of the beam. It is to be hoped that experiments will be made in regard to the deflection of beams and the distribution of stresses, so that some true relation can be determined, between this element, which is easily measured, and the other elements which are usually unknown: that is, in regard to the relation between deflections and the actual stresses of compression and tension.

Prof. Walter Rautenstrauch. I regret that more observations are not recorded and plotted in the paper and that the methods of making the computations and obtaining the data are not given. It would be interesting to plot the variation of deflection with load as observed, and as computed by the three formulæ selected for comparison.

2 I would ask Professor Lanza how he made his observations for the strain in both concrete and steel and also how he determined from these the neutral axis of the section. If these data were submitted it would be possible to make a comparison with results obtained by assuming other possible values of E, for example, and thus to ascertain to what extent the differences reported might be due to assumed and possible actual values.

3 As concrete construction is for the most part monolithic, and very few beams of the particular kind tested are used, I believe it is of much broader interest to investigate methods of measuring strain and computing stress than formulæ for simple beams. It is a fact, I believe, that all the data reported in this paper as actual stresses in concrete—actual stresses in steel—were obtained, not actually, from direct observations, but rather from relations between stress and strain assumed to exist in the concrete or steel. The same I believe is true in regard to the determination of the neutral axis. If Professor Lanza will tell us what assumptions he made in determining these values we will be in a better position to judge their worth.

4 I need hardly call attention to the fact that the modulus of elasticity for concrete in tension and compression is quite variable. It seems to depend upon the age of the concrete and the intensity of the stress. I believe it would have been of some value to take a slice from the end of these beams and obtain a stress-strain diagram, in order to compute the several values of E and the limits of stress for which each value of E is constant. Otherwise the actual values of the stress are not much more reliable than the values as computed by the formulae, since both are computed from assumed relations.

5 It is interesting to note that Formula B is based on a rational assumption concerning the variations in compressive stresses above the neutral axis. The fact has been well established that the stress varies as the ordinates of a parabola, and not as the ordinates of a straight line. On the other hand, I am inclined to doubt the statement of Considère that the concrete on the tension side can undergo an extension much greater than 0.02 per cent without cracking, when the beam is reinforced, whereas when not reinforced the concrete cracks when the extension is from 0.01 to 0.02 per cent. The mere fact that a reinforcing rod is present does not seem sufficient to change the physical properties of the concrete.

6 I believe Professor Turneaure has shown Considère to have been wrong in this assumption. It is not at all unlikely that Considère removed a piece of concrete in which no cracks had developed. Furthermore, if cracks are allowed to develop on the tension side—and this has frequently been observed in beams under working load—might not this crack gradually extend under repeated loading and seriously impair the safety of the structure?

B. H. Davis.[1] Certain practical considerations may be cited to

[1] Assistant Engineer, D. L., & W. R. R., Hoboken, N. J.

illustrate the difficulties confronting the experimenter seeking a rational solution of the deflection problem. Shrinkage is the worst, or perhaps the most indeterminate factor to be eliminated, since it spoils so many carefully performed experiments, being a large cause of the lack of uniformity so generally noted in experimental data.

2 The shrinkage of a concrete block 8 in. sq. by 2 ft. long has been shown to shorten appreciably a bar ½-in. square embedded in it and accurately measured before and after the setting of the concrete around it. This produces an initial tension in the concrete and an initial compression in the steel. In the case of a beam reinforced in only one plane, as perhaps some of the beams tested may have been, these initial strains may largely account for the lack of uniformity in the results obtained.

3 The shrinkage of concrete in setting, nearly always a variable factor, has almost completely upset the theory of arch-ring deflections when the arch centering is struck. Some settle very considerably upon striking the centering, especially when the arch ring is a monolith from skewback to skewback, while others settle hardly at all when alternate voussiors are made and allowed to set and shrink before the ring is keyed. Shrinkage, it has been proved, almost entirely causes this lack of agreement between the theoretical and the actual deflections when arch centers are struck. It would therefore seem logical to assume that the same cause figures prominently in the deflection phenomena of beams.

4 The shrinkage of a beam of large cross section, acting in opposition to that of a smaller beam, has been known to crack the weaker member from top to bottom, breaking up any dependence that might otherwise have been placed upon the concrete in tension, before the beam had been called upon even to support its own dead load.

5 In designing for a given load by the commonly accepted straight-line formulæ for obtaining stresses in steel and concrete, and using the prescribed unit stresses of the building code, a certain factor of safety results. In other words, an overload of two or three times the load assumed in the design, may be applied, and when removed, the structure should be just as capable of supporting the working load for which it was designed as before the overload was applied.

6 Now, granting the conclusion of the author, in Par. 27, that tension in the concrete materially affects the deflection and strength of beams (between certain limits of load), would it not still seem unwise to take advantage of this tension factor in any design where the assumed load limits might be overstepped at some time, leaving

the beam to serve the remainder of its period of usefulness without the tension factor counted upon in its design?

7 Almost every design is over-stressed sooner or later, occasionally by test load, but more often perhaps, because of the enthusiasm of some shop foreman in showing what his building will stand in the way of abuse. For example, loaded cars of gravel and broken stone, and later a 600-class standard-gage locomotive, were run across a machine and erecting shop floor that was designed for a uniformly distributed load of considerably less than one-half the concentrated moving loads applied, this without any apparent damage to the floor.

8 Settlement, which very often upsets carefully made calculations, causes even more indeterminate stresses in reinforced concrete than in other types of construction, this being due to the continuity and the monolithic character of the material. This fact further emphasizes the necessity for conservatism in working formulæ.

9 Construction joints, put in as they usually are, at points of maximum moment, make any reliance upon the concrete in tension entirely out of the question where such joints occur. It is not generally conceded that construction joints so located do materially weaken a beam except in shear.

10 A beam accidentally cracked entirely through near its middle, while being placed in a testing machine, tested higher than the average of several other beams of the same size and reinforcement, showing that a plane of fracture approximately normal to the center line of a beam had not, in this particular case, unfavorably affected the ultimate strength of a beam equally loaded at its third points.

11 Until more is definitely known concerning the shrinkage of concrete and the many other stresses in reinforced-concrete beams at present indeterminate as a matter of conservatism it would seem better to disregard tension in concrete as a moment-resisting factor.

Chas. B. Grady.[1] Professor Lanza and Mr. Smith have clearly brought out the fact that three of the formulae used for the design of reinforced-concrete beams are approximate with a load of one-third the breaking load. The writer will say a few words in reference to the use of these formulae in the design of beams.

2 Formulae *A* and *B*, which are used by a large number of engineers, do not allow anything for the tension in the concrete and therefore must give for rectangular beams results which are mere

[1] Asst. Mechanical Engineer, New York Edison Co.

approximations up to a point at which the concrete fails to act in tension, but the writer believes that if a comparison had been made at say double the load used, Formulae A and B would have given better results, and possibly nearer those found by actual test, than Formula C, especially for the value of σ_s (stress in steel per square inch).

3 In tests of similar beams made at Cornell University by Messrs. Paulus, Tripp and Davis, the average variation in the values of σ_s (stress in steel per square inch) deduced by formula A from those found by experiment was 34 per cent with a load of 4000 lb., and less than one per cent with a load of 8000 lb. The above figures are for five beams having an average breaking strength of 13,200 lb.

4 The errors in values deduced by Formulae A and B are more liable to be on the side of safety than the errors in values deduced by Formula C, and while there is no doubt that Formula C will give more accurate results when the stress in the steel is comparatively small, it is the opinion of the speaker that Formula C, and other formulae making allowance for the tension in concrete, should be used with caution.

5 It is the practice of many engineers to design reinforced-concrete beams in accordance with certain working stresses and to endeavor so to proportion the beam that it will fail by tension, that is, by either breaking or stressing the steel to a point considerably past its elastic limit, thus making the factor of safety a function of the stress in the steel. In such cases, no matter how much the concrete has helped out the steel under working conditions, when the beam is overloaded the steel must take care of practically the entire tension; and therefore the writer believes that it is wiser not to introduce a value for the tension in the concrete into the formulae used in the design of reinforced-concrete beams.

6 The speaker believes that the formulae for deflection deduced by Professor Lanza and Mr. Smith will be of great value to engineers, and that any one of the three formulae will give results accurate enough for practical purposes in figuring the deflections of T-beams, more of which are used in buildings than rectangular beams.

Frank B. Gilbreth. The most important subject related to reinforced concrete, from the standpoint of the mechanical engineer, is the design of forms, for it is the forms that afford the greatest opportunity for the saving of money, and the consequent reduction of price per cubic foot of new buildings.

2 Beams have been designed and built of rectangular section and over 64 ft. 0 in. long, and have beeen perfectly satisfactory. The most successful building of today as well as of the future must be designed with regard to the economical design and use of forms, and not to the greatest saving in the quantity of steel and concrete used. The forms are the most expensive single item of reinforced-concrete work, and a series of papers and discussions on economics of forms will be of more use to the members than any possible study of the savings that might come from refinements in the design of beams.

3 It is by no means rare to see designs for saving concrete where the value of the concrete saved amounts to much less than the cost of the special or odd-sized forms required.

PROF. WM. H. BURR. Much has been said about the disagreement of theoretical results with the results of experiments. That is an observation which may be made, I believe, in the case of every material which has ever been used by the engineer; scarcely more so of concrete, either plain or reinforced, than of other material. When a comparison of this kind is made, I think we should bear in mind, first, what theory is used.

2 The so-called common theory of flexure probably is not strictly applicable to any reinforced-concrete beam which has been broken. It is a theory which applies to a beam of very small depth, compared with the length of span. This is not the kind of beam usually found either in plain or reinforced concrete, and usually not even in steel. It is not a matter of surprise, therefore, that such a theory does not give the results found by experiment.

3 It seems to me we shall have to proceed with reinforced-concrete beams precisely as with beams of other material, viz: use a simple working hypothesis for the purpose of securing a formula in which empirical quantities determined by experiment may be used. That is the case with wrought-iron and steel beams, with timber beams, and with all other beams, and it is markedly so, even to a greater extent, with columns.

4 The three theories, *A*, *B* and *C*, may be considered in view of the varying conditions at different stages of stress. It would be difficult to show from any results of tests of concrete, that the law of distribution of stress in theory *B* is justified. There are some tests which show a graphic relation between the intensities of stress and strain, which approximates a parabolic curve, but probably no nearer

than a circular curve or some other. The majority of tests show that line much more nearly straight than parabolic within the limits of stress found in ordinary concrete beams.

5 It is true that concrete has considerable tensile resistance, when it possesses any, but I think there are few engineers who have used much plain or reinforced concrete, who would be willing to trust the tensile part of the beam to carry load, and to be so recognized in the working formula.

6 The result of the slight contraction of concrete, possibly not within the first two months, perhaps not within the first year of its life, is to create fine hair cracks. We do not know how far these enter the mass; they may be only skin-deep, but in some cases they are much deeper. Hence if the beam should show a continuous concrete structure on the tension side for the first two or three months, it does not follow that it is going to remain so. If we are to recognize such a possibility, and it seems to me we would not be justified in neglecting it, the only safe procedure is that usually followed, of neglecting tension in concrete. That does not mean that concrete may not sometimes have considerable tensile resistance. It simply means that such resistance cannot safely be recognized in ordinary concrete work.

7 These cracks may be very much reduced by continual wetting of concrete after it has been put in place. That is one direction in which the concrete work may be improved. We do not wet the concrete nearly enough after the forms are taken away. If it were feasible, concrete should be kept thoroughly wet from three to six months after being put in place. This is not practicable; but after the forms are taken away, the concrete should be kept soaked with water just as long as possible. The contraction will be less and there will be fewer hair cracks, but it will be impossible to eliminate them entirely.

8 We should be sensible, as engineers, in connection with reinforced-concrete work, precisely as we are or ought to be in everything else, and use the simplest possible formula, i. e., the straight-line formula, and not strain after some ultra-refinement which, when we come to examine it, has little or no solid basis. We should resort to proper theories and select a simple working hypothesis, and then use the test beams to determine such empirical coefficients or quantities as will make the resulting formulæ represent actual results as nearly as possible.

PROF. J. C. OSTRUP.[1] Within a short time, from fifteen to twenty years, at most, reinforced concrete has gained an enviable position in the construction world, and unquestionably, in spite of many inherent shortcomings, will better its reputation in the future among both engineers and laymen. It is, therefore, to be regretted that the trend of the authors' paper is toward a negative rather than a positive support.

2 It is a well-known fact that the greater number of the deductions and working formulæ obtained from the science of applied mechanics are based upon certain assumptions which to a greater or less, usually less, extent circumscribe the use of such formulæ. The errors resulting from these fundamental assumptions vary considerably with the different engineering materials with which we deal; they often vary considerably even with the same material, changing somewhat with the extreme fibre stress, the manner of application of the load, etc. The assumptions made in regard to the behavior of structural steel are probably nearer the absolute truth than for any other engineering materials, so near, in fact, that many engineers have come to regard the theory of steel design as following an unassailable mechanical law. Nevertheless this is not so.

3 On the other hand, the theory of reinforced concrete is based upon many assumptions, some of which can be better defended than others, and some of which have undergone, and will continue to undergo, modifications from time to time. It is also based upon many widely varying experiments which the experimenters themselves have been struggling to reconcile. Some of the most important of these assumptions, together with a brief account of their probable effect, are:

a That the applied forces in bending are perpendicular to the neutral axis.

4 This is incorrect, of course, inasmuch as the neutral axis under deflection follows a curve resembling a parabola. The resulting error is, however, extremely small.

b That a sectional plane, true before bending, also remains true after.

c That each fibre acts independently of adjacent fibres.

5 The last of these assumptions is particularly faulty, inasmuch as the ordinary reinforced beam usually has its reinforcement vary-

[1] Professor Structural Engineering, Stevens Institute of Technology.

ing in amount, both horizontally and vertically, throughout its length. In other words, unlike a rolled steel beam whose moment of resistance is uniform from end to end, the reinforced beam is not uniform in strength, the stronger parts tending to assist or restrain the weaker. The error from this assumption cannot be evaluated.

d That the concrete and the reinforcement will stretch or compress together without breaking the contact bond between them.

6 This condition, when complied with, as it infallibly must be in all cases, unquestionably sets up secondary local stresses, the magnitude of which cannot be even guessed.

e That there are no initial stresses.
f That the stress-strain curve for compression is a parabola.

7 The fulfillment, or the non-fulfillment, of the last two assumptions, is probably what causes the greatest divergence between theory and tests. A concrete beam is a casting, in a sense. If the mixture were perfectly uniform throughout, there would most likely not be any initial stresses due to the chemical action of setting. This is evidently not possible; hence throughout the beam there undoubtedly exist initial stresses of uncertain magnitude. This fact, in itself, would surely affect the stress-strain curve, but in addition we must consider the variable modulus of elasticity for the concrete. This varies not only in the same beam, according to unit stress in the extreme fibres, but also in beams of the same identical composition according to its depth, i. e., to the relation between the extreme fibre stress and the average fibre stress.

8 In addition to these mechanical considerations, we have many physical considerations governing the strength of concrete and reinforced-concrete beams. Such physical conditions must largely depend upon the personal equation of the engineer in charge; they may be guarded against, and their effect minimized but not wholly eradicated. When present, their influence can only be surmised.

9 To make this a little clearer let us assume a case where a number of beams were to be prepared for a testing machine and where great uniformity naturally would be sought; to insure which, only one grade of cement, one of sand and one of broken stone, would be employed. Next let us look into some of the more important points affecting the strength of concrete, as follows:

a Condition of the cement; whether all the bags in a cargo are of the same age, or manufacturing batch; quantity of carbonic acid contained; degree of moisture (since the outside bags in a stack, and even the outside layer in the same bag, often absorb considerably more moisture than the inside).

b Uniformity of quality of the sand; whether or not it contains in spots, loam, clay or other impurities, etc.

c Uniformity of the broken stone; whether or not the stones are alike in strength and texture; whether or not they are broken to a uniform size, etc.

d Quality or purity of the water; method of mixing the concrete, or difference in methods of mixing from batch to batch, even by the same gang.

e Tamping and placing of the concrete, including the often unavoidable variations in the degree of flexibility of the support between the ends and the center of the beam while the concrete is being tamped.

f Workmanship. A man is not a machine, consequently the materials mixed and the beams made, even by the same gang, will often vary considerably in spite of precautions. May not beams vary much more when made by different sets of workmen?

10 Besides the foregoing points affecting the mechanical laws governing the strength of the concrete, there are others; but enough have been indicated here to show that, when tested, a variation in their strength must exist.

11 Since each experimenter must base his deductions upon the results of his own observations, a divergence in the resulting formulæ is the natural result, and furthermore, were he to repeat the same tests under similar circumstances, his second results, in view of the foregoing, would vary from his first. With all this in mind, is it any wonder that closer agreement between the various working formulæ most generally in use, has not so far been reached? To an unbiased mind the wonder is that the divergences are not even greater.

12 Returning to the conclusions of the author, he states in Par, 24 " . . . . the observations made thus far are not sufficient to furnish the means for determining the actual distribution of the stresses, and hence for the deduction of reliable formulæ . . etc." This may be strictly true in theory, but will hardly be generally accepted as a matter of fact. On the contrary, it is quite within

good reason and good practice to deduce reliable formulæ, even where the action of some of the minor points involved is in doubt, so long as the effective range of such points is known. In this connection it may be recalled that concrete and masonry structures, centuries old, are still standing and doing effective service, though they were designed from formulæ and data far less reliable than those now at our disposal.

13 The author further says: "It follows therefore that whichever of the theories is adopted for practical use, it can be regarded only as a sort of working hypothesis." This, of course, is a sweeping condemnatory statement which, if it can be applied to the theory of reinforced-concrete construction, can, it is believed, be equally well applied to the theories underlying any form of construction; for no amount of theory, unaccompanied by practical experience and sound judgment, will prevail, either in the mechanical or in any other engineering field. This fact cannot be too strongly emphasized.

14 In Par. 26 the author states that theory C gives results in closer agreement with experiments than does either A or B. This is undoubtedly true, but so far as the evidence in Tables 5 and 6 is concerned, any one of the three theories is based upon "reliable formulæ" or, what is more to the point, the designs resulting from their use would be wholly reliable. As a matter of opinion, the preference should be for A or B, since they are nearly correct in regard to the unit stresses in the concrete,—the weaker material,—whereas they give somewhat smaller stresses for the steel than those expected.

15 It is equally true that no reliable deflection formulæ can be deduced without taking into consideration the tension in the concrete. We can, however, go a step further, and state that such formulæ, to be correct, must also include a provision for a deflection increment due to shear.

16 In concluding these remarks, the writer would suggest a caution to such alarmists as are prone to appear from time to time against a useful and excellent building material. No public good can result from arousing the apprehension of either engineer or layman with respect to reinforced concrete, and those of us who have had the opportunity of using it for a number of years cannot help but be impressed with its increasing serviceability and scope.

E. Lee Heidenreich.[1] The tests at the Massachusetts Institute of Technology, as well as those at the University of Illinois, were based upon a concrete mixture of 1 : 3 : 6, while those of Considère

[1] Special Engineer, N. Y. C. & H. R. R., New York City.

are based upon a mixture of 1 : $2\frac{1}{2}$: $2\frac{1}{2}$. I have repeatedly at meetings of the "Joint Committee" urged the desirability of employing stronger mixtures, and mixtures of a "maximum density" rather than a certain proportion; and I believe that with such stronger mixtures Formula C will come still nearer to a correct interpretation of stresses and strains. If so, is it not natural to hope that in our reinforced-concrete building constructions, lesser dimensions of beams and girders, thinner floor slabs, and consequently a reduced item of *dead load* will result, also materially reducing the present disadvantages of heavy columns and foundations?

2 The most wonderful constructions of tanks, reservoirs and bridges in Europe, have resulted from mixtures of 1 : 3 or 1 : 5, properly graded. Why should not our beam tests be based upon such mixtures, notwithstanding the fact that at first glance they may not appear commercially advantageous for building constructions? I wish to place myself again on record as advocating a larger percentage of cement and a mixture representing a maximum density of the ingredients

Prof. C. E. Houghton. The paper adds to our knowledge of the probable magnitude and sign of the errors due to the use of formulæ deduced from a simpler theory. When the size of a structural member has been calculated by the use of a formula known to give a greater value to the unit stress than actually exists, the designer need not worry about the safety of that member. If in addition the probable magnitude of the error is known, corrections may easily be made where it is considered necessary to reduce the cost or weight of the member.

2 The neglect of tensile resistance in calculations of the strength of reinforced-concrete beams finds a parallel in the common practice for the calculation of the strength of riveted joints. The friction between the plates unquestionably adds to the strength of the joint, yet as far as the writer knows, no theory has been accepted in American practice that considers this friction as acting. This friction, like the tensile resistance of concrete, may vary from zero to a maximum value, and therefore should be neglected, as neither can be depended on for additional strength.

3 All formulæ for the strength of reinforced-concrete beams contain a factor whose value is the ratio of the modulus of elasticity of steel to that of concrete, and any error made in the assumption of that value affects the result in the same proportion. The modulus of elasticity

of steel is practically a constant term, but that for concrete varies through a wide range of values depending to a certain extent on the proportions of cement, sand and broken stone used in the concrete.

4 With the large possible variation of this ratio in mind, it would seem reasonable to suppose that the probable error, either in assuming a straight-line law for the variation of the compressive stress in the concrete, or in the neglect of its tensile resistance, will be less than that due to the choice of the value of this ratio. What is needed is a value for this ratio, determined by applying the formula derived from the straight-line no-tension theory, to the results of a great many tests on specially prepared beams.

5 The number of variable conditions that would affect the results in any such investigation is so great that unless one of our national engineering societies will undertake it there seems to be but little prospect of obtaining anything more than an approximate value based on the results of compressive tests on concrete.

WM. WALLACE CHRISTIE. The writer is particularly interested in the applications of reinforced concrete in engineering work, and has had to do with the designing of a great many floors, foundations and other work. He agrees with Professor Burr, and others not prepared to accept or consider a theory of design of concrete-steel beams allowing tension in the concrete, or an increase by reinforcement of the ability of the concrete to resist tension.

2 After concrete work has been erected for a time, hair-cracks, and others more decided, often develop in the beams. An example of this has already been cited: a 70 ft. concrete girder, or longer, with its center, at least, resting on hard pine timbers.

3 With the large factor of safety necessary in the design of concrete-steel beams, one cannot go very far wrong in using any of the three methods mentioned, but the writer prefers a straight-line formula.

4 The paper deals in particular with beams, which in practice are seldom used, except as lintels, or over openings in building walls. The experiments conducted with these beams will not give the results obtainable by the use of T-beams, and the writer doubts whether the test of a single T-beam, made in the test room, will develop the same strength or other features, as a test made on a similar T-beam which is part of a floor system. The beam tested in the laboratory is not joined tightly with the rest of the floor, while in actual construction the iron would necessarily be secured to the other parts of the floor system.

THE AUTHORS. The data and the results of observation for the first five beams, which have been asked for, are contained in a paper by G. Lanza, published in the proceedings of The American Society for Testing Materials for 1906.

2 The modulus of elasticity of the concrete was obtained from tests made upon seven 8 in. by 8 in. by 60 in. plain compression pieces of the same age, materials and mixture as the beams. The values of E are as follows:

	2,479,000
	2,223,000
	2,367,000
	2,264,000
	2,670,000
	2,623,000
	2,341,000
Average	2,424,000

In our paper we have used 2,335000 in order to permit of the use of $r = 12$.

3 It may be added that the neutral axis was determined for each load from the strain diagrams (which are shown graphically in the paper referred to) at the intersection of the plotted line with the vertical datum line. Numerical details of the strains will be given in appendix A, as they seem to be desired.

4 As reference has been made to evidence tending to discredit Considère's theory regarding the ability of concrete to stretch when reinforced, it may be well to say that it is neither the object of the paper to discuss this question, nor to take sides for or against this theory. The history of the main part of the controversy is as follows:

5 The theory was attacked by Kleinlogel in an article published in Beton u Eisen, Hefts 2 and 4, 1904, in the light of certain tests which he had made. The two tests of Considère on page 1038 of our paper were made as a refutation of Kleinlogel's argument. An account of them may be found in Considère's book on reinforced concrete. A subsequent reply by Kleinlogel, and a reply to this by Considère, are to be found in Beton u Eisen, but no new matter is given.

6 In Beton u Eisen, Heft 11–1905, Professor Ostenfeld gives an account of the results of some computations made by him upon the beams tested by Kleinlogel, and in the light of these he says "Thus

far I regard Kleinlogel's tests as a beautiful though unwilling confirmation of Considère's theory." To this Kleinlogel replies in Beton u Eisen, Heft 1-1906, but this reply contains no new evidence.

7 Fear seems to be expressed by some that pointing out the very considerable discrepancies between the results of computation made by theory *A*, and the results obtained by experiment, is equivalent to a condemnation of all structures where theory *A* was used in the computations. No such condemnation, however, is intended by the authors. They believe, however, that the more we realize the facts in any case, the better prepared are we to use our judgment as engineers, in designing any construction.

8 Most of the arguments advanced in support of the entire sufficiency of theory *A* may be summarized as follows:

a The calculations can be more easily made.

b That the mere fact of neglecting the tension in the concrete results in safety, though practically all admit that the concrete does resist tension in the early stages.

c The use of construction joints, which often take the form of a vertical joint at the middle of the span when work on a given floor extends over a period greater than one day.

9 These matters will be considered in the same order:

a There is no doubt that the calculations are more easily made when theory *A* is used.

b Whichever of the three theories is used, it is not customary to calculate by means of it, the stresses which produce diagonal cracks, and it is a fact that in a very large percentage of the beams that have been tested, the failure has been due to these diagonal cracks. Hence it seems to us that until we have arrived at some means of making calculations to determine these stresses and strains in such a way that the calculated results shall have a fair degree of agreement with the results obtained by experiment, we can hardly claim to have an all-sufficient theory. Moreover, in the case of beam A-1, the only one for which the shear has been figured, it is greater when determined from theory *C* than when obtained from theory *A*, the difference being in one case 57 per cent.

c When a construction joint is introduced, the beam is necessarily weak, and until tests of such beams are made, we cannot claim to know what theory will apply to them.

10 Other considerations which it would seem worth while to discuss are the following:

a The presence of initial stresses due to shrinkage.

b The variation in the value of the compressive modulus of elasticity of concrete.

c The recommendation made by some that the formulæ to be used be based upon loads larger than one-third the breaking load, and by some upon the breaking load.

d The question of so proportioning the reinforcement that the breaking shall be due to the tension in the steel exceeding the elastic limit.

11 Discussing these in order we have:

a The presence of initial stress is of course a great source of uncertainty in reinforced concrete, as well as in cast iron, and hence we should expect irregularities due to this cause, the amounts of which are very difficult to estimate. Whether their influence is still large or not at one-third the breaking load, is a debatable question, though it must be comparatively less at one-third than at smaller loads. On the other hand, with loads greater than one-third the ultimate, the ratio of stress to strain becomes quite variable, and any rational formula becomes inaccurate.

b In the light of the experiments made by different men and in different places, it would seem to the authors that the variations of the modulus of elasticity for compressive stresses in the concrete, not more than one-third the ultimate, would not be very excessive.

c In the case of steel or other beams it is well known that the ordinary formulæ do not apply when the stresses in any of the fibres have passed the elastic limit; hence the difference between modulus of rupture and outside fibre stress at breaking.

d Regarding the question whether theory *A* will agree better with experiment when the percentage of reinforcement is kept so low that the elastic limit in the steel will be exceeded before any fibre of the concrete has to bear a stress equal to its crushing strength, the only evidence in the paper is the following: In one case the percentage of reinforcement was as low as 0.99 per cent, and in three others, 1.25 per cent, and in these three cases the discrepancies of theory *A* are large.

12 In general, it seems to us that thus far not enough systematic work has been done by way of experimenting and calculating in order that we may have more accurate knowledge about a number of matters, among which may be mentioned:

a The actual distribution of stresses not merely in the case of longitudinal reinforcement, but also with diagonal and other reinforcements, and also in T beams.

b A study of the diagonal tension, not only at the neutral axis, but elsewhere.

c A study of the conditions necessary that the breakage may always be due to the reinforcement exceeding the elastic limit, and whether diagonal cracks occur in those cases.

d A study of the effect of construction joints.

13 There only remain for discussion a few additional matters raised by different gentlemen. While it appears from the last column of Mr. Worcester's table that method *C* gives average results on the negative side, it must be remembered that they depend upon the value taken for t (the tensile strength of the mixture). This table, as well as Table 5, clearly shows that if a slightly lower value of t had been used for these six beams, their average error would have been a positive one, and also smaller than that by using *A*.

14 Replying to the question of Mr. Newman, we do not think the discussion of the Bethlehem beams is sufficiently relevant to the matter of this paper to be taken up here.

APPENDIX A

STRAINS FOR THE M. I T. BEAMS.

The strains were measured at four points in the depth of the beam on each side as described in the paper before the American Society for Testing Materials, already referred to. Columns 1, 3, 4, 2, in the following tables give the strains for these points. Points 3 and 1 were one and five inches, respectively, *above* the center of the beam, while points 4 and 2 were one and five inches, respectively, *below* the center.

BEAM A-1

One 1-inch Plain Rod. Age 53 Days.
Initial Load 1250 Lb. Breaking Load 15000 Lb.

Loads Lb.	Strains 1	Strains 3	Strains 4	Strains 2
2250	0.000023	−0.000008	0.000033	0.000060
3250	0.000064	−0.000009	0.000048	0.000108
4250	0.000107	0.000008	0.000057	0.000195
5250	0.000186	0.000022	0.000071	0.000262
6250	0.000228	0.000009	0.000124	0.000352
8250	0.000345	0.000005	0.000186	0.000569
10250	0.000448	−0.000022	0.000274	0.000795
12250	0.000543	−0.000026	0.000337	0.001017
14250	0.000672	−0.000088	0.000466	0.001279

BEAM A-2 FIRST APPLICATION

One 1-Inch Twisted Rod. Age 49 Days
Initial Load 1250 Lb. Breaking Load 16500 Lb.

Loads Lb.	Strains 1	Strains 3	Strains 4	Strains 2
2250	0.000044	0.000012	0.000003	0.000033
3250	0.000082	0.000012	0.000027	0.000093
4250	0.000138	−0.000013	0.000077	0.000174
5250	0.000172	0.000016	0.000073	0.000251
6250	0.000216	0.000018	0.000108	0.000358
8250	0.000317	−0.000004	0.000202	0.000595
10250	0.000405	−0.000009	0.000271	0.000835
12250	0.000505	−0.000063	0.000391	0.001039

BEAM B-3

Two ¾ in. Plain Rods. Age 43 Days.
Initial Load 1250 Lb. Breaking Load 15950 Lb.

Load Lb.	Strains. 1st application 1	3	4	2
2250	0.000073	0.000013	0.000017	0.000081
4500	0.000100	−0.000003	0.000059	0.000175
5250	0.000144	0.000015	0.000060	0.000223
6250	0.000195	0.000002	0.000096	0.000289
8250	0.000398	−0.000020	0.000182	0.000428
10250	0.000519	−0.000066	0.000301	0.000587

BEAM C-5

Four $\frac{3}{8}$ Inch Plain Rods.
Initial Load 600 Lb.

Age 35 Days
Breaking Load 16240 Lb.

Loads	Strains			
Lb.	1	3	4	2
2600	0.000083	0.000018	0.000026	0.000087
4600	0.000219	−0.000024	0.000133	0.000296
6600	0.000337	−0.000067	0.000239	0.000532
8600	0.000444	−0.000059	0.000297	0.000751
10600	0.000542	−0.000091	0.000406	0.001023
12600	0.000631	−0.000137	0.000525	0.001272
14600	0.000765	−0.000209	0.000653	0.001525

BEAM E-9 FIRST APPLICATION

Two $\frac{3}{4}$ In. Twisted Rods
Initial Load 1250 Lb.

Age 54 Days
Breaking Load 21000 Lb.

Load	Strains			
Lb.	1	3	4	2
2250	0.000037	−0.000012	0.000029	0.000037
4250	0.000107	0.000003	0.000046	0.000134
5250	0.000155	0.000008	0.000060	0.000175
6250	0.000202	0.000004	0.000081	0.000256
8250	0.000275	0.000004	0.000122	0.000402
10250	0.000403	0.000010	0.000161	0.000541
12250	0.000486	0.000003	0.000212	0.000680

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A.I.E.E. and A.I.M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Railway Association. Statistical Bulletin No. 59-A. *Chicago*, 1909.

Association of Licensed Automobile Manufacturers. Bulletin No. 18. July 1906. *New York*, 1906.

Baylor University. Report of the President and Trustees September-November 1909. *Waco*, 1909.

Board of Supervising Engineers, Chicago Traction. First Annual Report. *Chicago*, 1908. Gift of the Board.

Boston Transit Commission. Fifteenth Annual Report. *Boston*, 1909.

Calendar of the Sir William Johnson Manuscripts in the New York State Library. *Albany*, 1909. Gift of New York State Education Department.

Check List of Publications of the University of Wisconsin, 1909. *Madison*, 1909.

Chronological History of the Origin and Development of Steam Navigation. Ed. 2. By G. H. Preble. *Philadelphia*, 1895. Gift of Daniel Arthur.

Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal-Combustion Engines. (Bulletin No. 392, U. S. Geological Survey.) By R. M. Strong. *Washington, Govt.*, 1909.

Comparative Tests of Run-of-Mine and Briquetted Coal on the Torpedo Boat Biddle. (Bulletin No. 403, U. S. Geological Survey.) By W. T. Ray and H. Kreisinger. *Washington, Govt.*, 1909.

Final Hearing of Selden Automobile Cases. June 4, 1909.

Hobart College. Address to the Alumni. *Geneva, N. Y.*, 1909.

Incidental Problems in Gas-Producer Tests. (Bulletin No. 393, U. S. Geological Survey.) By R. H. Fernald and others. *Washington, Govt.*, 1909.

Instructions for Reforesting Land. By C. R. Pettis. *Albany, N. Y.*, 1909.

Life of Robert Fulton. By his friend, C. D. Colden. *New York*, 1817.

Machine Automatique a Tailler sans Gabarit les Engrenages Coniques. By Edmond Dubosc. (Extract from La Revue de Mécanique, May, 1905.) *Paris*, 1905.

Machinery. Vol. 1. 1894–1895. *New York*, 1894–1895. Gift of C. E. Kinne.

Manufacturers' Record's Annual Blue Book of Southern Progress, 1909. *Baltimore, Md.*, 1909. Gift of Manufacturers' Record.

The Monist. Complete Index to Vol. 1–22. 1890–1907. *Chicago*, 1908.

New Complete Dictionary of the English and Dutch Languages. Two Parts. Ed. 2. By I. M. Calisch. *Tiel*, 1890, 1892.

One Hundred Ton Modern Cyanide Plant. By C. C. Christensen. (In *Mining World*, Nov. 13, 1909.)

PRESENT ASPECT OF ELECTRIC LIGHTING. By H. W. Handcock and A. H. Dykes. Institution of Electrical Engineers, August 1909. Gift of Calvin W. Rice.

PREVENTION OF INDUSTRIAL ACCIDENTS. No. 1—General. *New York*, 1909. Gift of Fidelity & Casualty Co.

REPORT OF THE TESTS OF METALS AND OTHER MATERIALS, 1908. *Washington*, 1909.

SIERRA AND SAN FRANCISCO POWER COMPANY. Stanislaus Power Development. Reprint from Journal of Electricity, Aug. 21, 1909.

SOCIETY OF ENGINEERS OF EASTERN NEW YORK. List of Members, 1908. *Albany, N. Y.*, 1908.

STATUS OF THE ENGINEERING PROFESSION. By G. A. Thomas. *London*, 1909. Gift of Society of Engineers.

SUR LE CHOIX DE L'OBLIQUITÉ DE LA LIGNE D'ENGRENEMENT POUR LES ENGRENAGES A DÉVELOPPANTE CONSIDÉRATIONS THÉORIQUES ET PRATIQUES. By Edmond Dubosc. (Extract from La Revue de Mécanique, 1903.) *Paris*, 1903.

TECHNIQUE DU BALLON. By G. Espitallier. *Paris*, 1907.

TECHNISCHER VEREIN VON PHILADELPHIA. Statuten und Nebengesetze, 1907. *Philadelphia*, 1907.

THÉORIE DES DÉRAILLEMENTS PROFIL DES BANDAGES. By G. Marié. *Paris*, 1909. Gift of Dunod & Pinat.

UNIVERSITY OF WISCONSIN. Bulletin, Engineering Series. Vol. 4. Nos. 2–5. Vol. 5. Nos. 1–5. *Madison, Wis.*, 1908–1909.

UTILIZATION OF FUEL IN LOCOMOTIVE PRACTICE. (Bulletin No. 402, U. S. Geological Survey.) By W. F. M. Goss. *Washington, Govt.*, 1909.

WIRELESS INSTITUTE. *Proceedings*. Vol. 1. No. 4. *New York*, September 1909.

EXCHANGES

L'AÉROPHILE. Seventeenth Year. No. 21-date. *Paris*, 1909–date.

APPLICATIONS OF ELECTRICITY TO PROPULSION OF NAVAL VESSELS. By W. L. R. Emmet. Society of Naval Architects and Marine Engineers. November 1909.

BUILDING AND EQUIPPING THE NON-MAGNETIC AUXILIARY YACHT *Carnegie* with Producer Gas Propelling Equipment. By W. Downey. Society of Naval Architects and Marine Engineers, November 1909.

DEVELOPMENT OF THE GASOLINE POWER BOAT. By E. T. Keyser. Society of Naval Architects and Marine Engineers, November 1909.

ENERGY CHARTS FOR STEAM. Supplement to Power and the Engineer, March 16, 1909.

ENGINEERING DIRECTORY. No. 49. October 1909. *London*, 1909.

MASTER CAR BUILDERS' ASSOCIATION. Report of the Proceedings of the 43d Annual Convention. *Chicago*, 1909.

MATERIAL FOR HANDLING EQUIPMENTS FOR LAKE VESSELS. By R. B. Sheridan. Society of Naval Architects and Marine Engineers, November 1909.

NEW ENGLAND WATER WORKS ASSOCIATION. Index to the Transactions and Journal to December 1903, inclusive. *Boston*.

STRENGTH OF WATER TIGHT BULKHEADS. By W. Hovgaard. Society of Naval Architects and Marine Engineers, November 1909.

STRUCTURAL RULES FOR SHIPS. By James Donald. Society of Naval Architects and Marine Engineers, November 1909.

SYSTEM OF MATHEMATICAL LINES FOR SHIPS. By J. N. Warrington. Society of Naval Architects and Marine Engineers, November 1909.

TRADE CATALOGUES

E. W. BLISS CO., *Brooklyn, N. Y.* Steam turbines, direct connected to generators, blowers, pumps. 10 pp.

CELFOR TOOL CO., *Chicago, Ill.* Drills, reamers, chucks, and grinding machinery. 29 pp.

GEORGE N. COLE, *New York, N. Y.* Cross horizontal folding doors, "Canopy" and "Jack Knife" construction. 18 pp.

WILLIAM CRAMP & SONS SHIP AND ENGINE BUILDING CO., *Philadelphia, Pa.* Automobile and Motor boat castings, 45 pp.; Parsons' white brass ingots and manganese bronze ingots, 24 pp.; Propellers for motor boats, 19 pp.; Parsons' white brass, 8 pp.; Dimensions and price list of Parsons' manganese bronze rolled sheets and rods, 10 pp.

DARLEY ENGINEERING CO., *New York, N. Y.* Bulletin No. 4. Suction conveyor for coal and ashes. 16 pp.

DIAMOND POWER SPECIALTY CO., *Detroit, Mich.* Pamphlet No. 5: Economical production of steam. 8 pp.

DIEHL MFG. CO., *Elizabethport, N. J.* Bulletin No. 102 on type G motors and generators for general power purposes, 10 pp.; bulletin No. 151 on types F and FC motors and generators. 16 pp.

DODGE COAL STORAGE CO., *Philadelphia, Pa.* Handling and storing coal and ore, 112 pp.; Telpherage, an electrically operated system of transporting material, 60 pp.; Coal storage according to the Dodge System, 55 pp.

FLINCHBAUGH MFG. CO., *York, Pa.* Catalogue 9B: York gas, producer gas, gasoline, kerosene and alcohol engines, 48 pp.

GENERAL ELECTRIC CO., *Schenectady, N. Y.* Tungsten automobile electric lamps, 15 pp.; train lighting with G. E. Tungsten and Tantalum lamps, 5 pp.; Bulletin No. 4702: fire boats of New York, Chicago, San Francisco, etc., 16 pp.

GLASGOW IRON CO., *Pottstown, Pa.* Iron and steel plates, muck bars, flanged and pressed work. 94 pp.

INDUSTRIAL INSTRUMENT CO., *Foxboro, Mass.* Foxboro Recorder, November 1909. 16 pp.

JENKINS BROS., *New York.* Jenkins '96 packing. 1 p.

R. K. LEBLOND MACHINE TOOL CO., *Cincinnati, O.* Cutter and tool grinders. 40 pp.

LYON METALLIC MANUFACTURING CO., *Aurora, Ill.* Installation of Lyon Steel Factory Equipment in the George N. Pierce Co.'s Plant at Buffalo. 20 pp.

MAGNOLIA METAL CO., *New York, N. Y.* Anti-friction metal, 10 pp.; Metal used as babbitt, 8 pp.; Metal vs. Genuine (tin) babbitt, 24 pp.

NORTHERN ENGINEERING WORKS, *Detroit, Mich.* Newten Cupola, with a differential, adjustable tuyere system and an all steel air chamber. 12 pp

W. R. Ostrander Co., *New York, N. Y.* Speaking-tube hardware, electric bells and batteries, electric light material, telephone and telegraph instruments, and general electric supplies. 690 pp.

Robbins & Myers Co., *Springfield, O.* Standard motors and generators. 32 pp.

M. Rumely Co., *La Porte, Ind.* Oil pull tractor for plowing, hulling, and threshing. 18 pp.

Sawyer Tool Mfg. Co., *Fitchburg, Mass.* Price list of machinists' tools. 55 pp.

Scully Steel & Iron Co., *Chicago, Ill.* November 1909 stock list of iron and steel supplies. 96 pp.

Seneca Falls Mfg. Co., *Seneca Falls, N. Y.* Catalogue 22-B: screw cutting lathes, speed lathes and wood turning lathes and attachments. 36 pp.

Société des Ateliers Dubosc, *Turin, Italy.* Automatic machine for cutting conical gears, without pattern. 10 pp.

M. Steiner & Co., *Dayton, O.* Steiner gas and gasolene engines. 24 pp.

Stewart Heater Co., *Buffalo, N. Y.* Otis tubular feed water heater, oil separator and purifier. 16 pp.

Charles A. Stickney Co., *St. Paul, Minn.* Power pump feed, and gravity feed engines, 32 pp.; Bulletin No. 1137, 16 pp.

Joseph H. Wallace & Co., *New York, N. Y.* Representative industrial plants in the pulp and paper industries, and power plants. 200 pp.

Westinghouse Electric & Mfg. Co., *Pittsburg, Pa.* Circular 1094: Turbo-generator sets, 39 pp.; Circular 1103: Multiple arc lamps, direct current, 11 pp.; Circular 1177: Materials for switchboard panels, 11 pp.; Circular 1181: Portable direct current Ammeters and Voltmeters, 7 pp.

Williamson Submarine Corporation, *Norfolk, Va.* October 1909 Submarine Bulletin. 3 pp.

Wm. H. Wood, *Media, Del. Co., Pa.* Hydraulic machinery, 55 pp.; Loco fire box and tube plates, 16 pp.

UNITED ENGINEERING SOCIETY

Gift of J. McAllister Stevenson, Jr. and Louis T. Stevenson

Baker, T. Treatise on the Mathematical Theory of the Steam Engine. *London, 1864.*

Bennett, F. M. Steam Navy of the United States. *Pittsburgh, 1896.*

Bourne, John. Handbook of the Steam Engine. *New York, 1865.*

Haupt, Herman. General Theory of Bridge Construction. *New York, 1866.*

Nason, H. B. Manual of Qualitative Blowpipe Analysis. *Philadelphia, Pa., 1881.*

Nystrom, J. W. Technological Education and the Construction of Ships and Screw Propellers, for Naval and Marine Engineers. Ed. 2. *Philadelphia, 1866.*

Perry, M. C. United States Japan Exhibition. Vol. 1–3. *Washington, 1856.*

Turnbull, John. Short Treatise on the Compound Engine. *Glasgow, 1873.*

U. S. Coast Survey. Coast Pilot of Alaska. Pt. 1. 1869. *Washington, 1869.*

U. S. Navy Department. Report of the Secretary. 1867, 1873, 1876, 1880, 1885. Vol. 1. 1887. *Washington, 1867, 1873, 1876, 1880, 1885, 1887.*

U. S. Navy Department, Office of Naval Intelligence. Annual. July 1892. *Washington, 1892.*

WARD, J. H. Elementary Instruction in Naval Ordnance and Gunnery. *New York, 1861.*

Gift of Prof. F. W. Hutton

INTERNATIONAL EXPOSITION, St. Louis, 1904. Official Catalogue. Exhibition of the German Empire. *Berlin.*

TRADE CATALOGUES

AMERICAN MACHINE COMPANY, *Louisville, Ky.* Full magnet control electric elevators for passenger and freight service, 14 pp.; Description of ammonia regulator for refrigerating machines, 2 pp.; Description of dehydrator for ice and refrigeration machines, 2 pp.; Absorption system of ice making compared with the compression system, 2 pp.; Catalogue of ice and refrigerating machinery absorption system, 37 pp.

VILTER MANUFACTURING CO., *Milwaukee, Wis.* Catalogue A: Refrigerating and ice making machinery. July 1909; Catalogue F: Ammonia fittings for refrigerating and ice making plants; Partial list of users of improved ice making and refrigerating machinery. April 1909.

COMMENT ON CURRENT BOOKS

LARGE GAS ENGINES. By Percy R. Allen. Reprinted from Cassier's Magazine. 1909. Cloth, 7 by 9½; 61 pages; 22 illustrations.

The author has divided his subject into three parts: the four-cycle engine—British and Continental practice; the four-cycle engine—American practice; and two-cycle engines. He has described the characteristics of each type at some length, numerous illustrations showing assembled engines and details of construction.

CYRUS HALL MCCORMICK, HIS LIFE AND WORK. By Herbert N. Casson. *A. C. McClurg & Co., Chicago,* 1909. Cloth, 5½ by 8; xii + 264 pages; illustrated. Price $1.50.

The author is well known to readers of popular periodicals through his serials on The Romance of Steel and The Romance of the Reaper. In the present volume he has told of the early struggles and final success of the man who gave grain culture a wonderful impetus through his development of the reaper.

CONTENTS by chapter headings: The World's Need of a Reaper; The McCormick Home; The Invention of the Reaper; Sixteen Years of Pioneering; The Building of the Reaper Business; The Struggle to Protect Patents; The Evolution of the Reaper; The Conquest of Europe; McCormick as a Manufacturer; Cyrus H. McCormick as a Man; The Reaper and the Nation; The Reaper and the World; Give us this Day our Daily Bread.

STEAM NAVIGATION, A CHRONOLOGICAL HISTORY OF ITS ORIGIN AND DEVELOPMENT. By George Henry Preble, Rear-Admiral, U. S. N. Second Edition. *L. R. Hamersly & Co., Philadelphia, 1895.* Half morocco, 6½ by 9½; 418 pages.

The author starts with the first recorded steamboat experiment in 1543, at Barcelona, Spain, and continues his narrative up to the year 1882, the time of writing. The matter is arranged chronologically, the dates being placed as side heads, so that reference to the development in any year is easily made. The author has treated his subject in an interesting manner, incorporating something of an anecdotal quality to appeal to the lay reader. The fact that the author spent twenty-five years in collecting his material, speaks for its value as an engineering record.

MORRISON'S SPRING TABLES. By Egbert R. Morrison. Published by the author at Sharon, Pa. Cloth, 6 by 9; 84 pages. Price $2.

The author has presented a comprehensive list of formulae and tables for the design of light and heavy helical springs and sheet and plate elliptical springs. The properties of light helical springs have been arranged under graduated values of the fundamental ratio—the ratio of the diameter of the bar (or similar dimen-

sion in other than circular sections) to the mean diameter of the spring. The properties of heavy springs are tabulated under each size of bar or plate. From a table on rectangular and elliptical sections, used in connection with the other tables on helical springs, the properties of such springs may be determined easily by proportion. For helical springs the working basis has been taken as one inch of solid height, and for elliptical springs a plate one inch wide. Calculations are based on a fiber strain of 80,000 lb. per sq. in. The modulus of elasticity is taken as 12,600,000 for helical springs and 25,400,000 for elliptical springs.

CONTENTS: Part I, Formulæ: Notation; Helical, Round Bar, Single Coil, General; Helical, Rectangular Bar, Single Coil, General; Helical, Round Bar, Single Coil, Steel; Helical, Rectangular Bar, Single Coil, Steel; Helical, Concentric Coils; Elliptical, General; Elliptical, Steel. Part II, Mathematical Tables: Fractional Parts of π; Cubes; Fifth Powers. Part III, Spring Tables: Helical Wire, Light Steel Spring Table; Helical, Bar, Machinery and Railroad, Heavy Steel Spring Table, Helical, Rectangular and Elliptical Sections; Elliptical, Sheet, Light Steel Spring Table; Elliptical, Bar Carriage, Medium Weight Steel Spring Table; Elliptical, Plate, Machinery and Railroad Heavy Steel Spring Table; Elliptical, Take-up.

MECHANIC'S AND MACHINIST'S POCKET BOOK. Edited by Wm. H. Fowler. Second Edition. *Scientific Publishing Co., Manchester, England, 1909.* Cloth, 4 by 6, 448 pages, illustrated. Price 6d.

This information in this book is largely culled from British practice, though the editor has in some cases incorporated data obtained from the United States. This is particularly true of the chapter on gearing, the most extensive section of the book. The chapter on shop practice deals with a variety of subjects such as the tempering and working of metals, pattern making, allowances for fits, and the like. A diary for 1910 forms an appendix to the book.

CONTENTS: Handy References and Tables; Mensuration, Geometry, and Trigonometry; Use of Logarithms and Antilogarithms; Materials Used in Machine Construction; Machine Tool Design; Proportions of Machine Tool Parts; Metal Cutting Tools; High Speed Tool Steels; Drilling and Boring Metal; Screw Threads, Screw Cutting, and Taper Turning; Emery and Emery Wheels; Shop Practice; Wheel Gearing; Belt and Rope Driving, Shafting; Lifting Ropes and Chains.

THE PREVENTION OF INDUSTRIAL ACCIDENTS. By Frank E. Law, M.E., and William Newell, A.B., M.E. *Fidelity and Casualty Company of New York, New York.* Paper, 5 by 8; 194 pages; 72 illustrations. Price 25 cents.

The prevention of industrial accidents has been the subject of more than one address, and New York has now a museum exhibiting safety devices for the protection of life and limb, but no literature in book form on the subject has yet appeared, we believe, except the book before us. The information was largely supplied from the company's own experience, but other sources—books, technical journals and trade literature—have also been drawn upon. Those features of boiler, engine and elevator design and operation, which must be carefully considered from the standpoint of preventing accidents, are treated at some length, while the safeguarding of the operatives, in factories in general and those of wood-working machinery in particular, is also considered.

CONTENTS by chapter headings: Introduction; Care on the Part of Employers and Employee; Safety Devices; Steam Boilers; Engines; Electrical Apparatus; Elevators; The Factory; Wood-Working Machinery.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

01 Assistant professorship, in charge of design courses in engines, steam turbines, locomotive or gas engines, with assured advancement to full professorship in few years, for the right man. Institution desirous of having its men do outside work. Want a man of ability and experience. Position would pay initially from $1800 to $2000. Location, New York State.

02 A young technical graduate to carry out a series of brick-testing experiments. Previous experience not necessary. Work to last about one year with opportunity to continue on other work when brick testing is completed.

03 Technical graduate to act as general utility man in testing department of large steel works. Previous experience not necessary.

04 Designer of steam engines, compressors, etc., more especially accurate detailing for economic shop production. Position will pay about $2500. Location, New York.

05 Good opportunity is offered to a man with $15,000 to $25,000 capital, to join in an enterprise with a member who has a wide practical experience in manufacturing an electrical material for which there is an established and increasing demand.

06 Wanted, competent, practical operating engineer as chief engineer refrigerating plant of the Panama Railroad, Cristobal, Isthmus of Panama; experience with both refrigerating and electrical machinery essential. Good pay and quarters furnished. Exceptional opportunity for efficient man.

07 Mechanical Engineer to act as salesman for pipe and boiler covering materials; must be a good mixer without being a spendthrift. Salary $1500 to $1800 to start. Location New York.

MEN AVAILABLE

1 Technical graduate, Member, ten years engineering and sales experience, now employed as sales engineer, desires position in purchasing or sales department. New York.

2 Junior, graduate mechanical engineer, four years' experience design and installation; some experience with small gray-iron foundry.

3 Member, age 34, technical graduate, having experience in machine shop, drafting room, testing, estimating and office. Will consider position as manager of sales, or commercial position requiring a knowledge of machinery or engineering.

4 Graduate Lehigh University, class 1897, twelve years' experience as chief draftsman, designing engineer, mechanical engineer and superintendent. Automatic machinery and particularly that relating to printing and typewriting. Inventive and executive ability. Can handle men and take complete charge of the creation and manufacture of mechanical propositions and especially the development of new projects. Location, vicinity of New York.

5 Experienced designer of sugar machinery, in charge of drawing office, would like engagement with well-known manufacturers, as draftsman or erector; or would accept position as engineer in refinery or on plantation.

6 Member, past ten years chief engineer of complete design and construction of crushing plants, power plants, etc., past eight years entirely given to the design and construction of complete portland cement plants. Can furnish references to satisfy the most critical.

7 Mechanical and structural engineer with experience on furnace and mill design, buildings and general machinery, would like position as engineer or chief draftsman.

8 Mechanical and electrical engineer, at present employed as assistant to general superintendent, desires position as superintendent or engineer with concern manufacturing light or medium-weight machinery, or on engineering contract work. Long experience in both engineering and executive positions.

9 Specialist in steam turbine design, desires to locate with firm building steam or electrical machinery and contemplating the addition to present product of a line of steam turbines.

10 Graduate mechanical and electrical courses, W. P. I., age thirty-one, desires position in engineering or executive capacity. Experienced in engineering-contracting business, and construction; has installed, repaired and operated various types of gas, steam and electrical power equipment. Competent to prepare plans, specifications, estimates and reports. Six years on the Pacific coast and previously in New England. Salary $2500. Location immaterial.

11 Superintendent and manager desires change for larger opportunity; high grade organizer and executive; specialist on equipment, production and costs.

12 Shop manager and mechanical engineer; eighteen years experience in the design, manufacture and installation of heavy steam machinery, including hoisting and blowing engines, compressors, steam and hydraulic turbines. Eleven years in charge of factory operation. Best references.

13 Member desires position as works manager or general superintendent; twenty-four years experience as foreman, superintendent and manager of engineering works manufacturing high-class steam engines, boilers, air compressors and steam pumps; also cement mills. Good organizer and executive. If necessary prepared to invest in the right concern. West or Pacific Coast preferred.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALEXANDER, Ludwell Brooke (Junior, 1905), V. P., Haggerty Contr. Co., Davidson Ave. and Fordham Rd., and *for mail*, The Hazelhurst, 181st St. and Ft. Washington Ave., New York, N. Y.

APPLETON, Thomas (1893), Supt. of Constr., U. S. Public Bldgs., Alton, Ill.

AUSTIN, Adolph Odell (Junior, 1905), Asst. Engr., Vilter Mfg. Co., Milwaukee, Wis.

BAKER, Charles H. (Junior, 1903), 10 Relay Pl., Stamford, Conn.

BALDWIN, Abram T. (1899; 1902), Life Member; Solvay Process Co., and *for mail*, 689 Jefferson Ave., Detroit, Mich.

BARTH, Carl G. (1898), Cons. Engr., 1937 N. 33d St., Philadelphia, Pa.

BENET, Laurence V. (1892), Administrateur-Directeur, Société Anonyme des Anciens Établissements Hotchkiss & Cie, 21, Rue Royale, and *for mail*, 1, Ave. de Camoens, Paris, France.

BRANDON, Geo. Russell (1897; 1901), Harvey, Ill.

BRUSH, Frederick F. (Junior, 1900), Earlimart, Cal.

COLLETT, S. D. (1902), V. P. and Eastern Mgr., Elev. Supply & Repair Co., 114 Liberty St., New York, and *for mail*, 365 Sterling Pl., Brooklyn, N. Y.

CONRAD, Hugh Vincent (1887; 1891), Westinghouse Air Brake Co., Wilmerding, Pa.

GRIESS, Justin, Jr. (1898; Associate, 1908), Treas. and Sales Mgr., Interstate Engrg. Co., Builders Exchange, O.

HARRIS, Grenville A. (1907), Ch. Engr., Takata & Co., 50 Church St., New York, N. Y., and 176 Stiles St., Elizabeth, N. J.

HARTNESS, R. B. (Associate, 1903), 515 W. 124th St., New York, N. Y.

HEALD, Geo. W. (Junior, 1899), 7546 Eggleston Ave., Chicago, Ill.

HEALY, Frederick E. (1906), Mech. Engr. and Spec. Agt., Alberene Stone Co., and *for mail*, 415 3d St. N. W., Washington, D. C.

HECKER, H. A. (1906), 2032 Elm Ave., Norwood, O.

HUSSEY, Charles W. (Junior, 1908), 33 St. Andrews Pl., Yonkers, N. Y.

HYDE, Chas. E. (1885), 940 Fox St., Bronx, New York, N. Y.

LAVERY, Geo. L. (1886), Pres., Amer. Bank Equipment Co., 1315 Old Colony Bldg., and 4300 Ellis Ave., Chicago, Ill.

McCLATCHEY, A. F. (1889), 132 N. 4th St., Aurora, Ill.

McGEORGE, John (1891), Cleveland Engrg. Co., Cons. Engrs., New England Bldg., Cleveland, O.

MAHL, F. W. (Junior, 1892), Asst. to Dir. Maintenance and Operation, Union Pacific System and Southern Pacific Co., 135 Adams St., Chicago, and *for mail*, 1019 Michigan Ave., Evanston, Ill.

MILNE, James (1907), Cons. Engr., 304 Loo Bldg., Vancouver, B. C.

MONROE, Wm. Stanton (1896; 1901), Mech. Engr., Sargent & Lundy, 1720 Ry. Exchange Bldg., and 1235 N. State St., Chicago, Ill.

MORSE, Everett Fleet (1901), Morse Thermo Gage Co., 208 E. State St., and 111 Eddy St., Ithaca, N. Y.

NICKLIN, Ernest W. (1900; Associate, 1907), Mech. Engr., Detroit Brass Wks., and *for mail*, 421 Cadillac Blvd., Detroit, Mich.

PERRY, Wm. A. (1880), 1 Nassau St., and *for mail*, 7 E. 56th St., New York, N. Y.

ROWE, George F. (1908), 57 Penobscot St., Bangor, Me.

ROYLE, Vernon Elmer (Junior, 1905), Mech. Engr., John Royle & Sons, and *for mail*, 823 E. 28th St., Paterson, N. J.

SAMPLE, Morris De F. (Junior, 1905), Secy-Treas., Fire Protection Co., and *for mail*, 2901 Washington Blvd., Indianapolis, Ind.

SLEE, Norman S. (Junior, 1909), Engr. and Draftsman, Babcock & Wilcox Co., and *for mail*, 410 W. Park Ave., Barberton, O.

SMITH, Orin G. (Junior, 1899), Platt Iron Wks., 1224 Chemical Bldg., St. Louis, Mo.

SMITH, Otto T. R. (1906), Asst. Engr., Engrg. Dept., Otis Elev. Co., 17 Battery Pl., and *for mail*, 880 St. Nicholas Ave., New York, N. Y.

SORNBERGER, Edwin C. (1890), Allis-Chalmers Co., Ellicott Sq., and *for mail*, 208 Lancaster Ave., Buffalo, N. Y.

SWEET, Franklin (Junior, 1903), 285 Farwell Ave., Milwaukee, Wis.

THOMPSON, Edward P. (1884), M. E., Registered Pat. Atty., 1371 Columbia Rd., Washington, D. C.

WHITE, Edward F. (1891), Cons. Engr., Sulphur Plants, Pres., Rutland Mfg. Co., Rutland, Vt.

WICK, Henry (Associate, 1903), 416 Wick Ave., Youngstown, O.

NEW MEMBERS

AKERLIND, G. A. (1909), Cons. Engr., 664 Monadnock Bldg., Chicago, Ill.

BARKER, Perry (Junior, 1909), Chemical Engr., A. D. Little, Inc., 93 Broad St., Boston, Mass.

BORDE, George U. (1909), Cons. Engr., 914 Hibernia Bldg., New Orleans, La.

BOYER, Frederic Quintard (Junior, 1909), 216 Orchard St., New Haven, Conn.

BROWN, Stephen P. (1909), Engrs.' Club, 32 W. 40th St., New York, N. Y.

BULKELEY, Claude A. (1909), Ch. Engr., Board of Education, St. Louis, Mo.

CHAPMAN, Frank T. (1909), Prop., Chapman Mfg. Co., Marbridge Bldg., New York, N. Y., and Montclair, N. J.

CHESS, Harvey B., Jr. (Junior, 1909), 808 Aiken Ave., Pittsburg, Pa.

CROGHAN, John T. (Associate, 1909), Ch. Engr., Concord Elec. Co., and 15 Capitol St., Concord, N. H.

DAMON, Walter Henry (1909), Supt. of Generating, United Elec. Light Co., 87 Greenwood St., Springfield, Mass.

DILLON, Edward L. (1909), Rep., Fairbanks, Morse Co., and 1330a Clara Ave., St. Louis, Mo.

ERNST, Alfred F. (Junior, 1909), Brighton Mills, and *for mail*, 434 Lafayette Ave., Passaic, N. J.

ESSELSTYN, Horace H. (1909), Engr., Westinghouse, Church, Kerr & Co., 10 Bridge St., New York, N. Y., and *for mail*, 296 Vinewood Ave., Detroit, Mich.

FUCHS, Herman (1909), Mgr., Mexican Dept., Fairbanks, Morse Co., and 3910 Cleveland Ave., St. Louis, Mo.

GILMORE, George F. (1909), Local Engr., Am. Thread Co., and 109 Barre St., Fall River, Mass.

GOETZ, Fred. W. (Associate, 1909), Secy., Goetz & Flodin Mfg. Co., Clybourn Ave. and Willow St., and 5960 Kenmore Ave., Chicago, Ill.

HAZELTON, Robert T. (Junior, 1909), Designer, Bridgeford Mch. Tool Co., 225 Mill St., Rochester, N. Y.

HELLER, H. Howard (1909), Eastern Sales Mgr., Hill Clutch Co., 50 Church St., New York, N. Y.

HENES, Harry Wm. (Junior, 1909), 307 E. Green St., Champaign, Ill.

HOUGHTON, Clyde Arthur (Junior, 1909), P. H. B. & N. C. Ry. Co., Eidenau, Pa.

HUNTER, John (1909), Ch. Engr., Union Elec. Light & Power Co., and 4462 Laclede Ave., St. Louis, Mo.

JONES, William R. (1909), Engr. of Constr., Univ. of Pa., and *for mail*, 550 S. 48th St., Philadelphia, Pa.

KENYON, Wm. Houston (1909), Member of Firm, Kenyon & Kenyon, 49 Wall St., New York, N. Y.

KERR, William C. (1909), Mech. Engr., Philadelphia Rapid Transit Co., 9th and Dauphin Sts., and 3322 N. 17th St., Philadelphia, Pa.

KOCH, George B. (1909), Foreman, Loco. Testing Plant, Pa. R. R., and *for mail*, 809 Chestnut St., Altoona, Pa.

LORD, Chas. Edward (1909), Elec. Pat. Atty., Allis-Chalmers Co., Milwaukee, Wis.

LUNDGAARD, Ivar (Junior, 1909), Industrial Engr., Rochester Ry. & Light Co., and *for mail*, 34 Clinton Ave., Rochester, N. Y.

McCARTHY, Harry (1909), Ch. Draftsman, Natl. Tube Co., and 600 E. Prospect St., Kewanee, Ill.

McMILLAN, Chas. M. (Junior, 1909), Cons. Engr., King Edward Hotel, 145 W. 47th St., New York, N. Y.

MONAGHAN, James F. (1909), Mech. Engr., Waltham Bleachery & Dye Wks., and 2 Oak St., Waltham, Mass.

MORETON, George Wm. (1909), Genl. Supt., Betts Mch. Co., and 1323 Gilpin Ave., Wilmington, Del.

MOYER, Allen V. (Junior, 1909), Asst. Secy., Lyons Boiler Wks., P. O. Box 221, De Pere, Wis.

NEWLIN Alexander Z. (1909), Mech. Engr., Natl. Tube Co., and *for mail*, 600 S. Tremont St., Kewanee, Ill.

NORRIS, William H., Jr., (Junior, 1909), Engr., W. R. Grace & Co., and *for mail*, 1 Hanover Sq., New York, N. Y.

OHMES, Arthur K. (1909), Member of Firm, Nygren, Tenney & Ohmes, 87 Nassau St., New York, N. Y.

PALMER, George W., Jr. (1909), Elec. Engr., Old Colony St. Ry. Co., Boston & Northern St. Ry. Co. and Hyde Park Elec. Light Co., 84 State St., Boston, Mass.

PEDDLE, John Bailey (1909), Prof. Mch. Design, Rose Poly. Inst., and *for mail,* 2117 N. 10th St., Terre Haute, Ind.

RICHARDS, Willard F. (1909), Mech. Supt., Gould Coupler Co., Depew, N. Y.

ROELKER, Carl J. (1909), Cons. Engr., Roelker & Lee, State Bank Bldg., Richmond, Va.

ROHLIG, Georg G. (1909), Genl. Supt., Botany Worsted Mills, and 145 Dayton Ave., Passaic, N. J.

SHERWOOD, Mather Wm. (1909), Genl. Inspr., Board of Aqueduct Commrs., and *for mail,* 1090 St. Nicholas Ave., New York, N. Y.

SMITH, Harry J. (1909), Ch. Engr., Hill Clutch Co., Cleveland, O.

STROTHMAN, Louis E. (1909), Asst. Mgr., Pumping Eng. and Hyd. Turbine Dept., Allis-Chalmers Co., Milwaukee, Wis.

STROUSE, Sidney B. (Junior, 1909), Engr., Pa. Engrg. Co., and *for mail,* 1326 N. Marshall St., Philadelphia, Pa.

STURGIS, Wm. Bayard (Junior, 1909), Asst. Engr., Dover White Marble Co., Wingdale, Duchess Co., N. Y.

TYDEMAN, William A. (Junior, 1909), Secy., Macan Jr. Co., and 108 S. 2d St., Easton, Pa.

VANDERGRIFT, James W. (1909), Supt. National Transit Co., Southern Pipe Line Co., Crescent Pipe Line Co., and Eureka Pipe Line Co., and 665 W. Chestnut St., Lancaster, Pa.

WERST, Chas. Wm. (1909), Genl. Foreman, Erecting Dept., Baldwin Loco. Wks., Philadelphia, and *for mail,* 4603 Greene St., Germantown, Philadelphia, Pa.

PROMOTIONS

MARSHALL, Wm. Crosby (1901; 1909), Asst. Prof., Descriptive Geom. and Drawing, 114 Winchester Hall, S. S. S., Yale Univ., and *for mail,* 201 Edwards St., New Haven, Conn.

SCHREUDER, Andrew M. (1898; 1909), Supt., Phila. Textile Mchy. Co., Hancock and Somerset Sts., Philadelphia, and *for mail,* 6201 Germantown Ave., Philadelphia, Pa.

WALKER, Frederick Wiley (1898; 1909), V. P. and Ch. Engr., Comstock, Haigh, Walker Co., 1018–20 Ford Bldg., Detroit, Mich., and *for mail,* Cedarburg, Ozankee Co., Wis.

DEATHS

METCALF, William. SWINSCOE, Charles. WILLCOX, Chas. Henry.

GAS POWER SECTION

CHANGES OF ADDRESS

CHAPMAN, W. B. (Affiliate, 1908), Pres., Chapman Engrg. Co., 50 Church St., New York, N. Y.

COLLETT, S. D. See mem. Am. Soc. M. E.

HOPKINS, George Jay (Affiliate, 1909), Natl. Ry. Devices Co., 490 Old Colony Bldg., Chicago, Ill.

ROTH, Charles (Affiliate, 1909), Mech. Engr., Liquid Carbonic Co., Chicago, and *for mail*, 220 Marion St., Oak Park, Ill.

NEW MEMBERS

CUMMINGS, Wm. Warren. See mem. Am. Soc. M. E.

CUTLER, Frank G. (Affiliate, 1909), Steam Engr., Tenn. Coal, Iron & R. R. Co., Ensley, Ala.

DAVIS, Harvey N. (Affiliate, 1909), Instr., Harvard Univ., 509 Craigie Hall, Cambridge, Mass.

HAGUE, Charles A. See mem. Am. Soc. M. E.

HOBART, Douglas R. (Affiliate, 1909), Tech. Editor, Collier's, and *for mail*, 65 W. 93d St., New York, N. Y.

JENKINS, Alexander Lewis. See mem. Am. Soc. M. E.

MOSES, Frank D. (Affiliate, 1909), Pres., Gas Engrg. Co., Trenton, N. J.

MOSES, Percival R. (Affiliate, 1909), Cons. Engr., 45 W. 34th St., New York, N. Y.

MYERS, Cornelius T. See mem. Am. Soc. M. E.

SPURLING, O. C. See mem. Am. Soc. M. E.

STEVENS, Henry R. (Affiliate, 1909), Cons. Engr., 610 Bailey Bldg., Seattle, Wash.

STOUT, Oscar M. (Affiliate, 1909), Engr., 972 Dean St., Brooklyn, N. Y.

STRITMATTER, Albert (Affiliate, 1909), Secy. & Treas., Gas Engine Pub. Co., and 224 E. 7th St., Cincinnati, O.

TYLEE, Don O. (Affiliate, 1909), 1233 Washtenaw, Ann Arbor, Mich.

WINSHIP, W. E. See mem. Am. Soc. M. E.

STUDENT SECTIONS

CHANGES OF ADDRESS

CARNAHAN, O. A. (Student, 1909), 212 E. Clark St., Champaign, Ill.
COLEMAN, Wm. F. (Student, 1909), Rm. 337, Association Hall, Champaign, Ill.
HEILMAN, H. C. (Student, 1909), 1005 S. 4th St., Champaign, Ill.
JAPPE, Kurt W. (Student, 1909), Main Belting Co., 1241 Carpenter St., Philadelphia, Pa.
LUND, J. C. (Student, 1909), 305 S. Wright St., Champaign, Ill.
McGINNIS, H. D. (Student, 1909), H. B. Smith Co., Westfield, Mass.
WOLF, J. E. (Student, 1909), address unknown.

NEW MEMBERS

ARMOUR INSTITUTE OF TECHNOLOGY

BAUGHMAN, I. N. (Student, 1909), 3166 Lake Park Ave., Chicago, Ill.
BOLTE, E. E. (Student, 1909), 3757 Ellis Ave., Chicago, Ill.
BYERS, A. A. (Student, 1909), 7321 Union Ave., Chicago, Ill.
CARLSON, H. W. (Student, 1909), 2138 Walnut St., Chicago, Ill.
CROCKER, A. H., Jr. (Student, 1909), 650 Barry Ave., Chicago, Ill.
GENTRY, T. E. (Student, 1909), Hotel Metropole, 23d & Mich. Ave., Chicago, Ill.
GILBERT, J. B. (Student, 1909), 3325 Armour Avenue, Chicago, Ill.
GRENOBLE, H. S. (Student, 1909), 4312 Champlain Ave., Chicago, Ill.
GRIFFITH, F. H. (Student, 1909), 3343 Calumet Ave., Chicago, Ill.
HENWOOD, P. B. (Student, 1909), 300 E. 33d St., Chicago, Ill.
LOHSE, A. W. (Student, 1909), 3346 Dearborn St., Chicago, Ill.
McCAGUE, A. (Student, 1909), 140 No. Franklin Ave., Austin, Ill.
PARSONS, H. N. (Student, 1909), 3334 Armour Ave., Chicago, Ill.
THOMAS, W. E. (Student, 1909), 6500 Ellis Ave., Chicago, Ill.
WERNICK, F. E. (Student, 1909), 3316 Dearborn St., Chicago, Ill.
YOUNG, D. A. (Student, 1909), 3332 Armour Ave., Chicago, Ill.

BROOKLYN POLYTECHNIC INSTITUTE

SMALL, G. S., 3d. (Student, 1909), 61 Pierrepont St., Brooklyn, N. Y.

CORNELL UNIVERSITY

BATT, I. A. (Student, 1909), 115 College Ave., Ithaca, N. Y.
BOWER, F. A. (Student, 1909), 58 Thurston Ave., Ithaca, N. Y.
BROWN, C. S. (Student, 1909), 1 Central Ave., Ithaca, N. Y.

CANADY, M. S. (Student, 1909), 518 Stewart Ave., Ithaca, N. Y.
COMINS, H. N. (Student, 1909), 438 Cascad Bldg., Ithaca, N. Y.
CROSSMAN, D. M. (Student, 1909), 105 De Witt Pl., Ithaca, N. Y.
FAIRBANKS, F. L. (Student, 1909), 422 E. State St., Ithaca, N. Y.
GOLDBERG, M. S. (Student, 1909), 102 Highland Pl., Ithaca, N. Y.
GRAY, F. R. (Student, 1909), 113 De Witt Pl., Ithaca, N. Y.
HARDING, H. G. (Student, 1909), 704 E. Buffalo St., Ithaca, N. Y.
LINDSAY, H. D. (Student, 1909), 415 Stewart Ave., Ithaca, N. Y.
NIXDORFF, S. P. (Student, 1909), 221 Eddy St., Ithaca, N. Y.
PEACH, P. L. (Student, 1909), 306 Eddy St., Ithaca, N. Y.
REINICKER, N. G. (Student, 1909), 203 Williams St., Ithaca, N. Y.
REYNOLDS, H. B. (Student, 1909), 203 Williams St., Ithaca, N. Y.
SERRELL, J. J. (Student, 1909), 102 West Ave., Ithaca, N. Y.
SKINNER, H. A. (Student, 1909), Sheldon Court, Ithaca, N. Y.
TURNER, E. T. (Student, 1909), 404 Stewart Ave., Ithaca, N. Y.
UNCKLES, H. W. (Student, 1909), 226 Eddy St., Ithaca, N. Y.
WALL, R. E. (Student, 1909), 110 Osmun Pl., Ithaca, N. Y.
WESLEY, C. F. (Student, 1909), 203 College Ave., Ithaca, N. Y.
WING, S. R. (Student, 1909), 208 Dryden Rd., Ithaca, N. Y.
WOOD, A. P. (Student, 1909), 130 Dryden Rd., Ithaca, N. Y.
WOOD, S. V. (Student, 1909), 110 Osmun Pl., Ithaca, N. Y.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PAGE, Atwood C. (Student, 1909), 137 Newbury St., Boston, Mass.

UNIVERSITY OF ILLINOIS

KEOWN, B. L. (Student, 1909), 511 E. White St., Champaign, Ill.
MOSCHEL, H. (Student, 1909), 405 E. Green St., Champaign, Ill.

UNIVERSITY OF KANSAS

BRIGHAM, C. M. (Student, 1909), 23 E. Lee St., Lawrence, Mass.
HILFORD, W. H. (Student, 1909), 1025 Kentucky St., Lawrence, Kansas.
JOHNSON, C. E. (Student, 1909), 736 Maine St., Lawrence, Kansas.
PLANK, Wm. Jay (Student, 1909), 814 Alabama St., Lawrence, Kansas.

COMING MEETINGS

January and February

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the Editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

ALBERTA ASSOCIATION OF ARCHITECTS

January, annual meeting, Edmonton. Secy., H. M. Whiddington, Strathcona.

AMERICAN MATHEMATICAL SOCIETY

February 26, New York and San Francisco sections. Secy., F. N. Cole, 501 W. 116th St., New York.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

January 18–20, annual meeting, 29 W. 39th St., New York. Secy., W. M. Mackay, Box 1818.

AMERICAN SOCIETY OF HUNGARIAN ENGINEERS AND ARCHITECTS

January 8, 29 W. 39th St., New York. Paper: Measurement of Feeble High Frequency Currents, Aurel Kozmutza. Secy., Zoltán de Németh.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

January 11, February 8, 29 W. 39th St., New York. January 15, St. Louis. January 21, Boston. May 31–June 3, Spring Meeting, Atlantic City, N. J. July 26–29, joint meeting with Institution of Mechanical Engineers, England. Secy., Calvin W. Rice, 29 W. 39th St.

AMERICAN SOCIETY OF SWEDISH ENGINEERS

January 8, annual meeting, 271 Hicks St., Brooklyn, N. Y. Secy., E. Hammerstrom.

ASSOCIATION OF ONTARIO LAND SURVEYORS

February 22–24, annual meeting. Secy., Killaly Gamble, 703 Temple Bldg., Toronto.

BOSTON SOCIETY OF ARCHITECTS

January 4, annual meeting. Secy., E. J. Lewis, Jr., 9 Park St.

BOSTON SOCIETY OF CIVIL ENGINEERS

January 26, annual meeting, Chipman Hall, Tremont Temple. Secy., S. E. Tinkham, 60 City Hall.

CANADIAN SOCIETY OF CIVIL ENGINEERS

Quebec Branch, January 21, annual meeting, Montreal. Secy., C. H. McLeod, 413 Dorchester St., W.

CIVIL ENGINEERS SOCIETY OF ST. PAUL

January 10, annual meeting. Old State Capitol Bldg., 8 p.m. Secy., D. F. Jurgensen, 116 Winter St.

ELECTRIC CONTRACTORS' ASSOCIATION OF NEW YORK STATE
January 18, Utica, N. Y. Secy., Geo. W. Russell, 500 Fifth Ave., New York.

ENGINEERS CLUB OF PHILADELPHIA
February 5, annual meeting, 1317 Spruce St Secy., W. P. Taylor.

ENGINEERS SOCIETY OF PENNSYLVANIA
January 4, annual meeting, Harrisburg. Secy., E. R. Dasher, Gilbert Bldg.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA
January 18, annual meeting. Secy., E. K. Hiles, 803 Fulton Bldg., Pittsburg.

FRANKLIN INSTITUTE
January 28, February 11, Witherspoon Hall, Philadelphia, Pa. Lectures: Road Administration and Maintenance, L. W. Page; Recent Methods for the Production of Light, R. H. Bradbury.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS
January, annual meeting, Cairo. Secy., F. E. R. Tratman, 1636 Monadnock Blk., Chicago.

ILLUMINATING ENGINEERING SOCIETY
January 11, Royal Society of Arts, John St., Adelphi, London. Paper: Glare, its Causes and Effects, J. H. Parsons. Secy., L. Gaster, 32 Victoria St.

INDIANA ENGINEERING SOCIETY
January 14–16, annual convention, Indianapolis. Secy., Chas. Brossmann, Union Trust Bldg.

IOWA ENGINEERING SOCIETY
Fecruary 16–17, Cedar Rapids, Ia. Secy., A. H. Ford, Iowa City.

LOUISIANA ENGINEERING SOCIETY
January 8, Hibernia Bldg., New Orleans, La. Secy., L. C Datz, 321-322 Hibernia Bldg.

MICHIGAN AUTOMOBILE ASSOCIATION
January 25–26, Detroit. Pres., E. A. Skae, Hammond Bldg.

MICHIGAN ENGINEERING SOCIETY
January 12–14, annual meeting, Lansing. Secy., Alba L. Holmes, 574 Wealthy Ave., Grand Rapids.

MONTANA SOCIETY OF ENGINEERS
January 6–8, annual meeting, Butte. Secy., Clinton H. Moore.

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS
January 12, annual meeting, Madison Square Garden, New York. Secy., Benjamin Briscoe, 7 E. 42d St.

NATIONAL ASSOCIATION OF CEMENT USERS
February 21–25, Chicago. Secy., R. L. Humphrey, Harrison Bldg., Philadelphia.

NATIONAL CIVIC FEDERATION CONFERENCE
January 5–7, Washington, D. C. Secy., D. L. Cease, 281 Fourth Ave., New York.

NEBRASKA CEMENT USERS ASSOCIATION
Februrary 1–4, Lincoln. Secy., Peter Palmer, Oakland.

NEW ENGLAND GAS ASSOCIATION
February 16, 17, annual meeting, Boston. Secy., N. W. Gifford, East Boston.

NEW ENGLAND WATER WORKS ASSOCIATION
January 12, annual meeting. Secy., Willard Kent, 715 Tremont Temple, Boston, Mass.

NORTHWESTERN ELECTRIC ASSOCIATION
January, Milwaukee, Wis. Secy., R. N. Kimball, Kenosha, Wis.

PACIFIC COAST ELECTRIC AUTOMOBILE ASSOCIATION
February, Oakland, Cal. Secy., J. T. Halloran, 604 Mission St., San Francisco.

RICHMOND RAILROAD CLUB
January 11. Lectures: Block Signals, Chas. Stephens; Terminal Freight Handling, G. H. Condict. Secy., F. O. Robinson.

SOUTH DAKOTA INDEPENDENT TELEPHONE ASSOCIATION
January 11–13, Huron. Secy., E. R. Buck, Hudson.

SOUTHERN GAS ASSOCIATION
February 16, Chattanooga, Tenn. Secy., James Ferrier, Rome, Ga.

STEVENS ENGINEERING SOCIETY
January 4, 11, 18, 4.10 p.m., Stevens Institute, Castle Point, Hoboken, N. J. Papers: Engineering Efficiency, H. G. Stott, Mem.Am.Soc.M.E.; Warfare of the Future, Hudson Maxim; Features of Electrical Development, T. C Martin. Secy., R. H. Upson.

WESTERN SOCIETY OF ENGINEERS
January 12, annual meeting, Chicago. Secy., J. H. Warder, 1735 Monadnock Blk.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
January			
1	Amer. Soc. Hungarian Engrs. and Archts.	Z. deNémeth	8.30
5	Wireless Institute	S. L. Williams	7.30
6	Blue Room Engineering Society	W. D. Sprague	8.00
11	The American Society Mech. Engrs	Calvin W. Rice	8.15
12	American Society Engrg. Contractors	D. J. Haner	7.30
13	Illuminating Engineering Society	P. S. Millar	8.00
14	American Institute Electrical Engineers	R. W. Pope	8.00
18–20	Heating and Ventilating Engineers	W. M. Mackay	All day
18	New York Telephone Society	T. H. Lawrence	8.00
21	New York Railroad Club	H. D. Vought	8.15
26	Municipal Engineers of New York	C. D. Pollock	8.15
February			
2	Wireless Institute	S. L. Williams	7.30
3	Blue Room Engineering Society	W. D. Sprague	8.00
5	Amer. Soc. Hungarian Engrs. and Archts.	Z. de Németh	8.30
8	The American Society Mech. Engrs	Calvin W. Rice	8.15
10	Illuminating Engineering Society	P. S. Millar	8.00
11	American Institute Electrical Engineers	R. W. Pope	8.00
15	New York Telephone Society	T. H. Lawrence	8.00
18	New York Railroad Club	H. D. Vought	8.15
23	Municipal Engineers of New York	C. D. Pollock	8.15

OFFICERS AND COUNCIL

PRESIDENT

GEORGE WESTINGHOUSE .... Pittsburg, Pa.

VICE-PRESIDENTS

GEO. M. BOND .... Hartford, Conn.
R. C. CARPERTER .... Ithaca, N. Y.
F. M. WHYTE .... New York

Terms expire at Annual Meeting of 1910

CHARLES WHITING BAKER .... New York
W. F. M. GOSS .... Urbana, Ill.
E. D. MEIER .... New York

Terms expire at Annual Meeting of 1911

PAST PRESIDENTS

Members of the Council for 1910

JOHN R. FREEMAN .... Providence, R. I.
FREDERICK W. TAYLOR .... Philadelphia, Pa.
F. R. HUTTON .... New York
M. L. HOLMAN .... St. Louis, Mo.
JESSE M. SMITH .... New York

MANAGERS

WM. L. ABBOTT .... Chicago, Ill.
ALEX. C. HUMPHREYS .... New York
HENRY G. STOTT .... New York

Terms expire at Annual Meeting of 1910

H. L. GANTT .... Pawtucket, R. I.
I. E. MOULTROP .... Boston, Mass.
W. J. SANDO .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. SELLERS BANCROFT .... Philadelphia, Pa.
JAMES HARTNESS .... Springfield, Vt.
H. G. REIST .... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

WILLIAM H. WILEY .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

ARTHUR M. WAITT .... New York

HONORARY SECRETARY

F. R. HUTTON .... New York

SECRETARY

CALVIN W. RICE .... 29 W. 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Jesse M. Smith, *Chairman*
Alex. C. Humphreys
F. R. Hutton
F. M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (1), *Chairman*
Edward F. Schnuck (2)
Geo. J. Roberts (3)
Robert M. Dixon (4)
Waldo H. Marshall (5)

HOUSE

Henry S. Loud (1), *Chairman*
William Carter Dickerman (2)
Bernard V. Swenson (3)
Francis Blossom (4)
Edward Van Winkle (5)

LIBRARY

John W. Lieb, Jr. (4), *Chairman*
H. H. Suplee (1)
Ambrose Swasey (2)
Leonard Waldo (3)
Chas. L. Clarke (5)

MEETINGS

Willis E. Hall (1), *Chairman*
Wm. H. Bryan (2)
L. R. Pomeroy (3)
Charles E. Lucke (4)
H. de B. Parsons (5)

MEMBERSHIP

Henry D. Hibbard (1), *Chairman*
Charles R. Richards (2)
Francis H. Stillman (3)
George J. Foran (4)
Hosea Webster (5)

PUBLICATION

Arthur L. Williston (1), *Chairman*
D. S. Jacobus (2)
H. F. J. Porter (3)
H. W. Spangler (4)
Geo. I. Rockwood (5)

RESEARCH

W. F. M. Goss (5), *Chairman*
Jas. Christie (1)
R. C. Carpenter (2)
R. H. Rice (3)
Chas. B. Dudley (4), *Deceased.*

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

SPECIAL COMMITTEES

1909

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
A. P. Trautwein
G. T. Voorhees
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
G. M. Basford
F. R. Hutton
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
Charles Whiting Baker
L. D. Burlingame
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
William J. Baldwin
Geo. M. Bond
Stanley G. Flagg, Jr.

On Thurston Memorial

Alex. C. Humphreys, *Chairman*
R. C. Carpenter
Chas. Wallace Hunt
J. W. Lieb, Jr.
Fred J. Miller

On Standards for Involute Gears

Wilfred Lewis, *Chairman*
Hugo Bilgram
E. R. Fellows
C. R. Gabriel
Gaetano Lanza

On Power Tests

D. S. Jacobus, *Chairman*
Edward T. Adams
George H. Barrus
L. P. Breckenridge
William Kent
Charles E. Lucke
Edward F. Miller
Arthur West
Albert C. Wood

On Land and Building Fund

Fred J. Miller, *Chairman*
James M. Dodge
R. C. McKinney

On Student Branches

F. R. Hutton, Honorary Secretary

SOCIETY REPRESENTATIVES

1909

On John Fritz Medal

HENRY R. TOWNE (1)
AMBROSE SWASEY (2)
F. R. HUTTON (3)
CHAS. WALLACE HUNT (4)

On Board of Trustees United Engineering Societies Building

CHAS. WALLACE HUNT (1)
F. R. HUTTON (2)
FRED J. MILLER (3)

On Library Conference Committee

J. W. LIEB, JR., CHAIRMAN OF THE LIBRARY COMMITTEE OF THE AM. SOC. M. E.

On National Fire Protection Association

JOHN R. FREEMAN
IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS
F. W. TAYLOR

On Government Advisory Board on Fuels and Structural Materials

GEO. H. BARRUS
P. W. GATES
W. F. M. GOSS

On Advisory Board National Conservation Commission

GEO. F. SWAIN
JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS
FRED J. MILLER

NOTE.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

OFFICERS OF THE GAS POWER SECTION

1909

CHAIRMAN
J. R. Bibbins

SECRETARY
Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman, *Chairman*
G. I. Rockwood
F. R. Hutton
H. H. Suplee
F. R. Low

GAS POWER MEMBERSHIP COMMITTEE

H. R. Cobleigh, *Chairman*
A. F. Stillman
H. V. O. Coes
G. M. S. Tait
A. E. Johnson
George W. Whyte
F. S. King
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

Cecil P. Poole, *Chairman*
E. S. McClelland
R. T. Kent
C. T. Wilkinson
C. W. Obert

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
L. S. Marks
H. R. Cobleigh
T. M. Phetteplace
G. D. Conlee
G. J. Rathbun
R. S. de Mitkiewicz
W. Rautenstrauch
L. V. Goebbels
S. A. Reeve
L. N. Ludy
A. J. Wood
A. L. Rice

GAS POWER INSTALLATIONS COMMITTEE

L. B. Lent, *Chairman*
A. Bement
C. B. Rearick

GAS POWER PLANT OPERATIONS COMMITTEE

I. E. Moultrop, *Chairman*
J. D. Andrew
W. H. Blauvelt
V. Z. Caracristi
E. P. Coleman
C. J. Davidson
W. T. Donnelly
H. J. K. Freyn
N. T. Harrington
J. B. Klumpp
G. L. Knight
J. L. Lyon
D. T. MacLeod
V. E. McMullen
C. H. Parker
J. P. Sparrow
A. B. Steen
F. W. Walker
C. W. Whiting
Paul Winsor
T. H. Yawger

GAS POWER STANDARDIZATION COMMITTEE

C. E. Lucke, *Chairman*
E. T. Adams
Arthur West
James D. Andrew
J. R. Bibbins
H. F. Smith
Louis C. Doelling

OFFICERS OF STUDENT BRANCHES

STUDENT BRANCH	AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	....	C. F. Hirshfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	C. F. Gebhardt	N. J. Boughton	M. C. Shedd
Leland Stanford, Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	P. H. Van Etten	H. L. Hess
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. A. Kirk	J. R. Jackson
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	H. S. Coleman	John Garver
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	W. F. Colman	S. G. Wood
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York	November 9	....	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Fredk. A. Dewey	A. P. Truette
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	H. B. Cook	P. G. Haines
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	....	....
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. E. Dudley	E. C. Phillips
Univ. of Nebraska, Lincoln, Neb.	December 7	....	....	....